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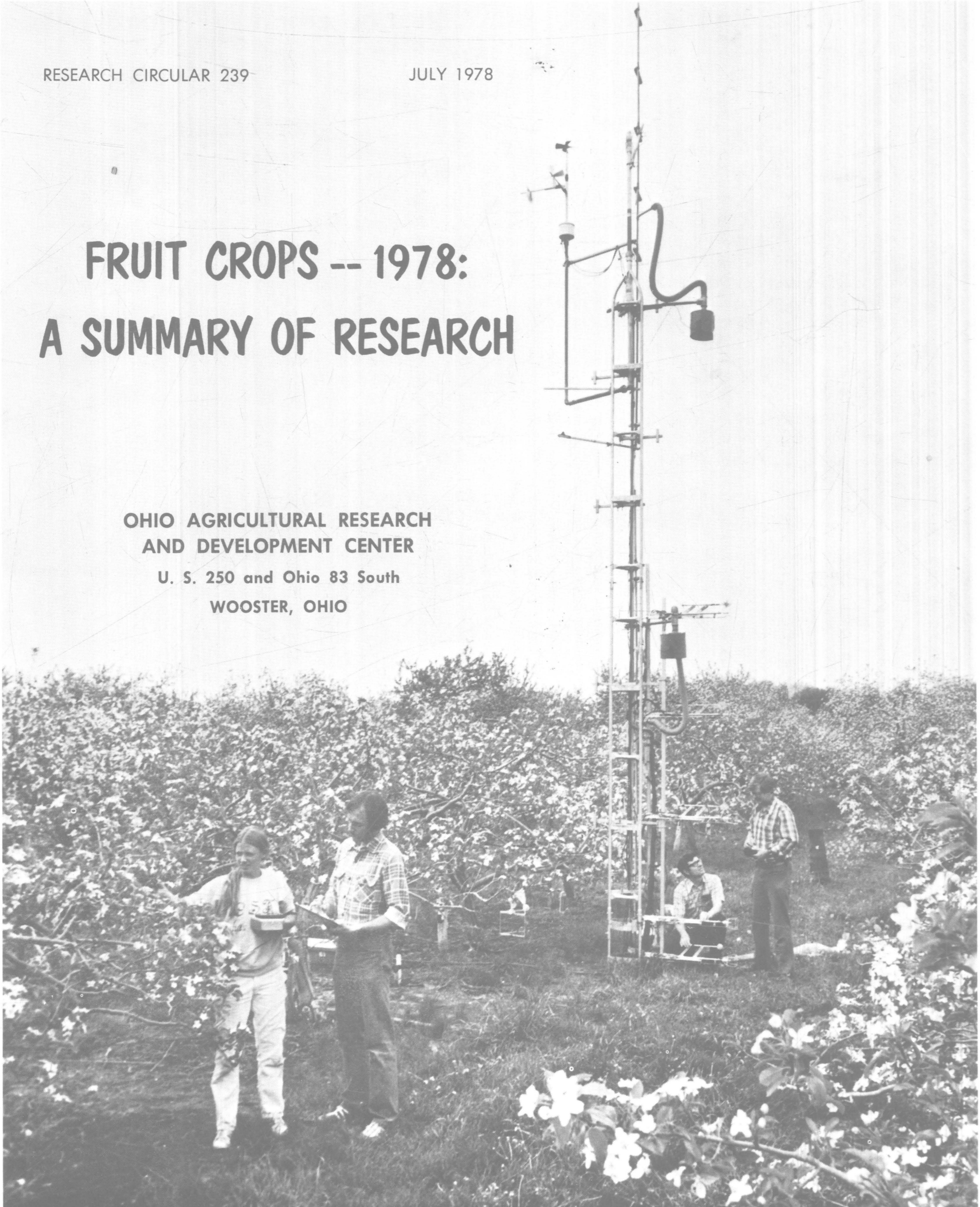
FRUIT CROPS -- 1978: A SUMMARY OF RESEARCH



OHIO AGRICULTURAL RESEARCH
AND DEVELOPMENT CENTER
U. S. 250 and Ohio 83 South
WOOSTER, OHIO

CONTENTS

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ON THE COVER: A cooperative research effort among several departments to study light distribution, canopy development, and air turbulence is being conducted in mature apple trees on M 9 dwarfing rootstock. Diane Doud and Bradley Taylor (left), Dept. of Horticulture graduate research associates, are determining light intensity at various locations in the canopy. Dr. Robert Fox, agricultural engineer, USDA—Science and Education Administration, Federal Research, and Dr. Franklin Hall, professor of entomology, OARDC, adjust equipment to measure wind speed and air turbulence. These studies are part of a total effort designed to control factors which will result in increased production efficiency in the orchards of tomorrow.

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Planting Distances vs. Yields and Amount of Pruning Time of Peach Trees

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INTRODUCTION

If Ohio fruit growers expect to realize a profit from their enterprise today, they need to obtain high yields without incurring excessive high costs of production. Consequently, a trend has developed towards high density plantings of apples (1, 5) and, in more recent years, of peaches as well (2, 6).

Important consideration in the management of high density fruit plantings must be given to training and pruning of the trees (3). With increased numbers of trees per acre, higher yields earlier in the life of the planting are obtainable. Accompanying this increase, however, might be higher labor costs as with pruning. Studies reveal that pruning is responsible for more than 30% of the cost of growing apples (4). This could well be the situation relative to peach production.

MATERIALS AND METHODS

A high density peach planting consisting of 270 trees was established at the Jackson Branch of the Ohio Agricultural Research and Development Center in April 1969. The cultivars are 'Redhaven' and 'Redskin', with 'Halehaven' used for buffer trees. The trees were set at a distance of 20 feet between the rows and at distances of 20, 15, 10, 7½, and 5 feet within the row. On an acre basis, these planting distances result in 109, 145, 218, 290, and 436 trees per acre, respectively. The plots ranged from as few as 4 trees at the 20-foot distance to 19 trees at the 5-foot spacing. The plots are approximately 85 feet in length, depending on the number of trees present.

RESULTS AND DISCUSSION

Yields obtained in 1971 from plots with the various tree spacings are shown in Table 1. This was the third year for the life of the planting. It is apparent that at this early age of the planting there was an increase in plot yield, and correspondingly on an acre basis as the planting distance between trees was reduced.

The weight of prunings in 1972 and the pruning time in 1973 are given in Table 2. In this planting, the plots containing the closer spaced trees required a greater amount of pruning when determined by weight or time in the early years of the planting. It could be that in some high density plantings the increased return the grower receives from higher yields might be somewhat reduced due to higher pruning costs.

As a result of low winter temperatures and/or spring frosts or freezes, none or only minor crops were obtained for 3 years following 1971. However, in 1975 a good crop was obtained and by this time the trees at the wider spacings had equaled the yields of trees at the closer planting distances (Table 3).

Vegetative growth of the trees in this planting was most vigorous, particularly when small or no crops were produced, and considerable pruning time was involved, especially in plots with trees spaced 5 and 7½ feet apart. Pruning was most important here to keep trees from shading each other and getting

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TABLE 1.—Yields of Peach Cultivars at Jackson, Ohio, 1971.

Planting Distance	Bushels/Acre	
	'Redhaven'	'Redskin'
ft		
20	35.3	43.6
15	86.7	83.5
10	97.2	96.2
7½	180.7	145.5
5	194.8	177.7

TABLE 2.—Tree Spacing and Relation to Pruning.

Planting Distance	Pruning Weight per Plot, 1972	Pruning Time per Plot, 1973
ft	lb	min
20	32	105
15	55	163
10	72	204
7½	93	319
5	107	326

TABLE 3.—Yields of Peach Cultivars at Jackson, Ohio, 1975.

Planting Distance	Bushels/Acre	
	'Redhaven	'Redskin'
ft		
20	297.9	618.8
15	405.4	722.0
10	352.0	641.2
7½	451.9	515.4
5	365.1	633.1

TABLE 4.—Tree Spacing and Relation to Pruning, 1973-1978.

Planting Distance	Pruning Time per Plot (min)						
	1973	1974	1975	1976	1977	1978	Cumulative 1973-1978
ft							
20	105	91	59	52	46	43	396
15	163	113	89	76	71	73	585
10	204	157	86	78	71	69	665
7½	319	201	118	70	54	60	822
5	326	180	113	119	91	121	950

too tall. Time required for pruning continues to be greater for plots containing closer spaced trees (Table 4).

It appears from these data that less pruning time is required as the trees become older. Part of this difference is due to the fact that the data presented represent dormant pruning time which was usually carried out in March. Since 1974, summer shearing or hedging has been used in this planting to help to control height and spread of these vigorous trees. This summer pruning has reduced the time required for the dormant pruning in recent years.

Given a couple more favorable years for a crop, the excessive vegetative growth of the closer spaced (5 and 7½ feet) trees would undoubtedly have been reduced, along with some reduction in pruning labor. In addition, during the first 5 years or so of the planting, the total yields of the plots with closer spaced trees would likely have been even more impressive as compared to plots with 15 and 20-foot spaced trees.

Naturally, these early crops are most welcomed by the grower, giving him a quicker return on his investment of land, trees, materials, and labor. However, until ways are available to help provide for a crop more consistently by misting before or at bloom or other means, the full potential of earlier, larger yields of higher density plantings may not be realized.

LITERATURE CITED

1. Emerson, F. H. and R. A. Hayden. 1975. High Density Tree Walls. HortScience, 10(6):550.
2. Hayden, R. A. and F. H. Emerson. Dec. 1973. Close Ranks for More Peaches. Amer. Fruit Grower, pp. 13-15.
3. Hull, Jerome, Jr. Jan. 1972. Prune for an Easier Harvest and Quality Peaches. Amer. Fruit Grower, pp. 15-17.
4. Kelsey, M. P., S. B. Harsh, and H. Belter. 1971. Economics of Apple Production in Southwestern Michigan. Mich. State Univ., Agri. Econ. Rpt. No. 184.
5. Ohio Crop Reporting Service. June 1976. 1976 Ohio Fruit Tree and Vineyard Survey.
6. Stembridge, G. E. and C. E. Gambrell, Jr. Dec. 1976. High Density Peaches Go Full Tilt. Amer. Fruit Grower, pp. 8, 11.

Influence of Heading Height of Newly Planted Trees on Apple Tree Growth[1]

DAVID C. FERREE[2]

INTRODUCTION

Recommendations for many years have been to prune 1-year apple whips at 24" to 36" after planting with little regard for differences in cultivar response (1, 2, 3). These recommendations have been satisfactory because almost all trees were relatively large, free-standing, and trained to either a modified leader or open center. In the new intensive management systems which restrict tree height to 7' to 8', the location of the first tier of scaffold shoots becomes critical if maximum production efficiency is to be achieved.

In slender spindle systems, Wertheim (7) suggests procuring feathered nursery trees and not whips as is the normal practice with conventional trees. The only pruning cut recommended on these trees at planting time is to cut the central leader at 32". Norton (4) follows this technique for trees to be grown as slender spindles and has suggested pruning at 24" and rubbing off buds below the central leader down to 14" to develop the first tier of scaffolds in trellis plantings. Tukey (6) has suggested heading newly planted trees at 16" just below the bottom wire (18") for trellis plantings.

Since cultivars appear to differ in the distribution of growth as the result of heading cuts, two studies were established to determine the response of newly planted trees on various cultivars to different heading heights.

MATERIALS AND METHODS

Study 1

In the spring of 1975, nine cultivars on either MM 106 or M 7 at a spacing of 15' x 25' were planted at the Moreland Fruit Farm, Moreland, Ohio. The trees were headed at heights of 24", 27", and 30" replicated 6 times for a total of 18 trees of each cultivar. Shoot growth was measured after completion of growth in the following three heights on each tree: top 3" (3" immediately below the cut); 3" to 6"; and below 6" (6" below the cut to the bud union).

Study 2

Jonathan and Golden Delicious on M 9 at a spacing of 8' x 12' and Spur Delicious on M 9 (Millerspur 14", 16", 20") and Oregon Spur (24") at a spacing of 6' x 12' were planted in 1977 by Downes Orchard, Inc., with the trees managed on a four-wire trellis. The trees were headed at 14", 16", 20", and 24". In the 20" and 24" treatments, one or two buds were left immediately below the cut to develop a central leader. Further shoots were rubbed off down to a height of 14" and all shoots below 14" were allowed to grow.

The treatments were replicated 10 times with 5 trees of each cultivar in each replication for a total of 50 trees receiving each treatment. After cessation of growth, shoot growth was measured as previously described.

RESULTS AND DISCUSSION

Summarization of the data from nine cultivars in Study 1 on M 7 and MM 106 revealed that more shoots were produced with a heading height of 30" than 24", but no difference in total shoot growth or average shoot length resulted from the various heading heights (Table 1). The highest number of shoots occurred in the area 3" below the heading cut and shoots in this zone had the greatest total shoot length and longest average length. The shoots in this zone would be the most desirable to develop as scaffolds.

[1]Appreciation is expressed to Fred Finney, Moreland Fruit Farm, and Bruce Downes, Downes Orchard, for their cooperation in these studies.

[2]Associate Professor, Dept. of Horticulture, Ohio Agricultural Research and Development Center and The Ohio State University.

TABLE 1.—Influence of Height of Heading Cut and the Production and Distribution of Growth of Newly Planted Apple Trees.*

	Height of Heading Cut			Distribution of Growth		
	24"	27"	30"	Top 3"	3"-6"	Below 6"
Number of Shoots	1.9b†	2.1ab	2.3a	2.6a	1.5c	2.2b
Total Shoot Length (cm)	62a	68a	69a	92a	41c	66b
Average Shoot Length (cm)	29a	29a	27a	37a	24b	25b

*Average of 162 trees of nine cultivars.
†Means without a letter in common are statistically different (.05).

TABLE 2.—Differences in the Response of Nine Cultivars in the Distribution of Shoot Growth of Newly Planted Apple Trees.*

Cultivar	No. of Shoots Top 3"	No. of Shoots 3"-6"	No. of Shoots Below 6"	Total Shoot Growth Top 3"	Total Shoot Growth 3"-6"	Total Shoot Growth Below 6"	Av. Shoot Length Top 3"	Av. Shoot Length 3"-6"	Av. Shoot Length Below 6"
Double Red Jonathan	2.7	1.5	1.7	122	53	56	45	33	31
Empire	2.7	2.0	3.2	78	46	76	29	23	24
Cortland	2.6	1.5	1.0	79	35	25	30	24	18
Idared	2.4	1.3	3.6	66	38	110	29	27	29
Double Red Stayman	2.9	1.8	4.3	127	66	148	44	34	36
Red Chief Delicious	2.4	0.6	8.9	51	9	18	21	7	12
Mutsu	2.5	1.8	2.4	101	50	68	38	30	25
MacSpur	2.6	1.3	1.8	83	39	58	34	20	23
Paulared	2.8	1.2	1.2	121	34	39	43	22	25
	LSD .05 = 0.7			LSD .05 = 25			N. S.		

*Average of growth from 24", 27", and 30" heading heights.

However, often the crotch angle was narrow and shoots lower down had to be selected. The use of wooden snap clothespins on these upper shoots could aid in forcing a wide, strong crotch.

In the area 3" to 6" below the heading cut, fewer shoots were produced and these shoots had less total and average shoot length, although the crotch angles were wider and more desirable. Many of the shoots in the zone 6" below the cut to the bud union were too low for desirable scaffolds and would have to be removed to facilitate good cultural practices.

A comparison of the distribution of shoot growth produced by the nine cultivars indicates that without exception more shoots were produced in the 3" immediately below the cut than in the area 3" to 6" below the cut (Table 3). There was more total growth and longer average shoot length in the top zone. Shoots below the top zone of Red Chief Delicious were very short and unsuitable for development as scaffolds, which is characteristic for many Spur Delicious sports.

In the area 6" below the cut and the bud union, Idared, Double Red Stayman, and Red Chief Delicious produced more shoots than were produced in the top 3" area. Shoots in the middle and lower zones of Double Red Jonathan, Empire, Idared, Double Red Stayman, and Mutsu were numerous enough and of sufficient vigor that heading height was not critical. The heading height for cultivars such as Red Chief Delicious must be chosen carefully if scaffolds are to be selected from the more desirable vigorous shoots.

In Study 2, the 14" heading height resulted in the longest central leader in Spur Delicious. Although a trend existed for the lower heading heights to produce longer central leaders in the other cultivars, the effect was not well defined (Table 3).

In 1931 Oskamp (5) evaluated for growth distribution from various severities of pruning on newly planted 2-year apple trees. He found that the more severe pruning resulted in terminal growth which was longer and had greater dry weight with fewer growing points.

Central leaders in Study 2 on the trees headed at 24" tended to be shorter than trees with the lower heading heights. Heading heights had little effect on the number of shoots produced or total growth per tree of Golden Delicious and Spur Delicious. The 16" heading height resulted in the longest central leader and more shoots and more total growth per tree in Jonathan than the other treatments. Heading heights of 20" or 24" and removing buds to the

TABLE 3.—Influence of Heading Height* on Length of the Central Leader, Number of Shoots per Tree, and Total Shoot Growth per Tree of Three Cultivars on M 9.

Heading Height	Length of Central Leader (cm) Golden Delicious	Length of Central Leader (cm) Jonathan	Length of Central Leader (cm) Spur Delicious	Total No. of Shoots/Tree Golden Delicious	Total No. of Shoots/Tree Jonathan	Total No. of Shoots/Tree Spur Delicious	Total Shoot Length/Tree Golden Delicious	Total Shoot Length/Tree Jonathan	Total Shoot Length/Tree Spur Delicious
in									
14	77b†	73cd	60cd	2.9de	4.4c	3.3cd	112d	214bc	105de
16	72ab	86a	45f	2.7de	9.8a	3.1cde	85de	453a	89de
20	68c	66de	38f	2.5de	4.3c	3.3cd	67de	173c	90de
24	59e	58e	43f	2.7de	5.7b	1.8e	78de	232b	51e

*Trees cut at 20" and 24" had buds below the top two rubbed off down to 14", with shoots below 14" allowed to remain.
†Means without a letter in common are statistically different (.05).

14" level did not result in increased growth of any of the cultivars.

Jonathan and Spur Delicious headed at 14" or 16" produced the greatest percent of their shoots and shoot growth in the zone 3" below the heading cut (Table 4). Shoots on Golden Delicious were more evenly distributed in the top 3" zone and the 3"-6" zone. Nearly 70% of the shoots and growth of Spur Delicious occurred immediately below the cut when it was made at 14". Growth distribution changed significantly when the heading cut was raised to 16", with only 36% of the shoots and 39% of the growth occurring in the 0-3" zone. Since these treatments were both on Millerspur, the difference can't be explained by strain differences.

No difference in the distribution of growth occurred with Jonathan headed at either 14" or 16", but Golden Delicious produced a greater percentage of its shoots and more growth in the upper zone when headed at 14" compared to 16". The reasons for the differences in cultivar response are not obvious but such differences must be considered when different cultivars are combined in management systems such as the trellis where the distribution of scaffold shoots is critical to production efficiency.

The 14" and 16" heading heights resulted in relatively few shoots or little growth in the zone 6" below the cut to the bud union (Table 4). The removal of buds or young shoots from below the central leader to a height of 14" on trees headed at 22" to 24" resulted in more than 60% of the shoots and total growth occurring in the zone from 14" to the bud union. The much larger size of this zone on these trees probably accounts for the appearance of increased growth in this zone. As noted earlier (Table 3), total number of shoots or total shoot growth/tree were not increased by these treatments.

By heading at 20" to 24" and rubbing off buds to 14", it is possible to tie the tree to the lower wire immediately and avoid any growth reduction caused by the wind moving the tree. However, in this study the wires were not in place and none of the trees were tied during the first growing season.

In Study 1, the higher heading heights resulted in more total growth, which was not found in Study 2. However, the 20" and 24" treatments had buds removed and this could account for the difference. The extra management step involved in removing the buds would not seem justified based on the results of this study. However, if a growth advantage could be achieved by tying the first season, the practice may have merit.

With cultivars such as Jonathan, Empire, Idared, Stayman, or Mutsu, which branch freely 10" to 12" below the heading cut, heading height is not critical. Heading cuts of 24" to 30" for free-standing trees and 16" for trellis trees are suggested. With cultivars such as Spur Delicious which produce most of their vigorous shoots within 3" of the heading cut, heading height should be adjusted so that scaffolds will be positioned where they are desired. For free-standing trees, the heading cut should be only 3" higher than the desired location of the first tier of scaffolds.

Since 2/3 of the uppermost shoots on Spur Delicious will have very narrow crotch angles, wooden snap clothespins snapped around the leader when the shoots are 3" to 4" long are recommended to insure strong crotch angles in these shoots. For trellis plantings, Spur Delicious should be headed no higher

TABLE 4.—Influence of Heading Height* of Three Cultivars on Shoot Distribution of Newly Planted Apple Trees on M 9 Rootstock.

	Distribution of Growth								
	Top 3" Below Cut†			3"-6" Below Cut			6" to Bud Union		
Heading Height	Golden Delicious	Jonathan	Spur Delicious	Golden Delicious	Jonathan	Spur Delicious	Golden Delicious	Jonathan	Spur Delicious
in									
	Percent No. of Shoots								
14	39c‡	56b	69a	50ab	36dc	24dc	11d	8d	6d
16	9de	59b	36c	58a	24de	46bc	33c	16c	18d
20	7de	7de	17d	19e	25de	17e	67b	68b	66b
24	6e	5e	13cd	3f	1f	18e	84a	94a	61b
	Percent Shoot Length								
14	40c	58b	74a	49ab	34c	19d	11d	7d	7d
16	8de	59b	39c	60a	24cd	47b	32c	17d	14d
20	6de	6de	16d	19d	26cd	19d	67b	68b	65b
24	5e	6de	13de	3e	1e	19d	84a	94a	60b

*Trees cut at 20" and 24" had buds below the top two rubbed off down to 14", with shoots below 14" allowed to remain.
†Does not include the central leader.
‡Means without a letter in common are statistically different (.05).

than 14" to produce a desirable branch orientation on the bottom wire (18"). Heading at 16" results in the side shoots being pulled nearly horizontal when they are attached to the bottom wire. This severe bending will result in greatly reduced growth in the area of the trellis where maximum growth is desired. Vigorous, undesirable watersprouts also will be produced at the point of the bend.

LITERATURE CITED

1. Banta, E. S., F. S. Howlett, and R. G. Hill, Jr. 1970. Pruning and Training Fruit Trees. Ohio State Univ., Coop. Ext. Serv., Bull. 528, 24 pp.
2. Childers, N. F. 1973. Modern Fruit Science. Hort. Pub., 960 pp.
3. Crowe, A. D. 1975. Apple Growing in Eastern Canada. Agriculture Canada Pub. 1553.
4. Norton, R. L. 1977. Training and Pruning Young Apple Trees. N. Y. Coop. Ext. Serv.
5. Oskamp, J. 1931. The Effect of Pruning Apple Trees at Planting Time. Cornell Univ., Agri. Exp. Sta. Mem. 138.
6. Tukey, L. D. 1967. Trellis Apple Production for Orchard Mechanization. Pa. Fruit News, 46(12):6-14.
7. Wertheim, S. J. 1970. The Training of the Slender Spindle of Four Apple Varieties. Proefstation voor de Fruitteslt Wilhelminadorp, Pub. No. 10, 158 pp.

Problems of Nitrogen Nutrition of Mature Apple Trees on M 9 Rootstock

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INTRODUCTION

The increasing use of trees on clonal size controlling rootstock, particularly in the most dwarfing M 9, has created a need for more precise information on the proper fertilization of these trees.

Although various investigations (4, 7, 8) have found some differences in nutrient uptake of dwarf vs. standard sized trees, it is generally agreed that alteration of nutrient uptake is not the mechanism causing dwarfing. Most current fertilizer applications are based on recommendations (1, 5) of foliar analysis and tree age. Such recommendations make no adjustment for tree size as influenced by rootstock. The amount of nitrogen fertilizer required to maintain adequate leaf nitrogen levels and sustain optimum shoot and fruit growth in mature dwarf trees has not been determined.

METHODS AND MATERIALS

In 1972, two rates and forms of nitrogen fertilizer were applied to mature trees on M 9 which previously had been uniformly fertilized. The Jonathan trees were planted in 1956 and Delicious and Golden Delicious in 1957, with all trees spaced 10' x 18' and supported by wooden posts. The soil is a fertile silt loam.

The fertilizer treatments consisted of: 1) a check with no fertilizer applied; 2) ammonium nitrate (NH_4NO_3) at ½ lb/tree; 3) NH_4NO_3 at 2 lb/tree; 4) sulfur coated urea (SCU)[2], a slow-release nitrogen form, applied at a rate equivalent to 2 lb of NH_4NO_3 with a 15% dissolution rate of urea reduced the first 7 days; 5) SCU at the rate equivalent to 2 lb of NH_4NO_3 but with a 30% dissolution rate. The treatments were arranged in a randomized block with four replications and four trees per treatment. The trees were chemically thinned each year with additional hand thinning when needed.

Annual nitrogen applications before 1972 were equivalent to or greater than ⅛ lb NH_4NO_3/yr for each year of tree age. The average nutrient levels found in the tree foliage in 1972 were: phosphorus, 0.23%; potassium, 1.56%; calcium, 1.01%; magnesium, 0.32%; manganese, 131 ppm; and boron, 20 ppm.

In 1972 and 1973, the fruit from each tree were graded on an FMC weight-sizer and the number of fruit in each of the following size classes recorded: size 1—3⅛ inch diameter and larger; size 2—2⅞ to 3 1/16 inch diameter; size 3—2 5/16 to 2 3/4 inch diameter; and size 4—smaller than 2¼ inch diameter. The fruit in size classes 1 through 3 were graded on commercial standards and culled fruit were removed and counted. In 1974 and 1975, the fruit from two trees/treatment/replication were graded. A 20-fruit sample of size 2 fruit from each tree was rated for russet and color in 1972 through 1974.

Samples of 40 mid-terminal leaves per tree were collected the first week of August each year and dried in a forced draft oven, ground through a 40 mesh screen, and analyzed for total nitrogen by the Kjeldahl-Gunning method.

RESULTS AND DISCUSSION

General Yield Patterns

The cropping pattern of the trees indicates that early yields were not high (Table 1). The original treatments on these trees consisted of various degrees of fruit removal which may partially explain the low

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[2]Experimental material supplied by the Tennessee Valley Authority.

TABLE 1.—Average Yield and Total Accumulated Yield per Tree of Three Cultivars on M 9 Rootstocks, Wooster, Ohio.

	Average Yield*								Total Accumulated Yield	
	1960-1963		1964-1967		1968-1971		1972-1975			
Cultivar†	lb/t	bu/a	lb/t	bu/a	lb/t	bu/a	lb/t	bu/a	lb/t	bu/a
Jonathan	18	104	48	278	101	584	116	669	1136	6567
Golden Delicious	15	88	56	319	124	715	129	741	1294	7467
Delicious	23	130	48	278	103	590	172	993	1383	7963

*Set 10' x 18' or 242 trees/acre.
†Jonathan planted 1956, Golden Delicious and Red Delicious planted 1957.

TABLE 2.—Influence of Soil Applied Nitrogen Sources and Rates on Leaf Nitrogen Content and Fruit Color and Russet of Golden Delicious on M 9.

Treatment	Rate (lb/Tree)	Average Leaf Nitrogen Concentration (%)*				Color†			Russet†		
		1972	1973	1974	1975	1972	1973	1974	1972	1973	1974
Check	0	2.58	2.36	2.34	2.28	2.6	2.6	2.9	1.7	1.9	2.0
NH_4NO_3	0.5	2.64	2.33	2.43	2.29	2.5	2.7	3.2	1.7	2.0	2.2
NH_4NO_3	2.0	2.76	2.49	2.49	2.36	2.8	2.9	2.8	1.7	2.2	2.2
SCU 15%	2.0	2.68	2.37	2.44	2.42	2.7	2.8	3.0	1.7	2.0	2.2
SCU 30%	2.0	2.68	2 37	2.42	2.23	2.8	2.4	2.8	1.6	2.1	2.2

*August sample of 40 mid-terminal leaves.
†Graduated rating system color 1 = yellow to 5 = green; russet 1 = no russet to 5 = complete russet.

early yields. However, from 1968 to 1975 yields of all three cultivars exceeded an average of 575 bushels per acre. Before 1972, Golden Delicious was the most productive cultivar. Frost severely reduced the Delicious crops in 1966, 1967, and 1971 which, coupled with a natural tendency for vigorous growth of standard habit Delicious, resulted in the Delicious trees averaging 2 to 3 feet greater in both spread and height than the other cultivars. Since 1972, Delicious has been the most productive cultivar. A heavy fruit set and inadequate thinning resulted in a very large yield in 1975 when the three cultivars exceeded 1,000 bushels/acre.

Nitrogen Relationships

Golden Delicious leaf nitrogen content was slightly lower in all treatments in 1973 through 1975 than the initial values in 1972 (Table 2). However, the rates of application or nitrogen forms had no influence on leaf nitrogen concentration in any year of the study. The Wooster silt loam soil in this study has a relatively high cation exchange capacity and historically has been rather slow to produce changes in nutrient uptake by deeply rooted trees. The nitrogen levels in all years were relatively high and other nutrients were well above deficiency levels.

The nitrogen treatments had no significant influence on fruit color or russet of Golden Delicious. The range of nitrogen rates used and the 4-year duration of the study would have been expected to result in noticeable shifts in leaf nitrogen levels. Other studies on this soil type have resulted in differences within 4 years. Smith (6) found that 'Murcott' Tangerine devitalized by excessive cropping did not respond to extra fertilizer. He found that starch depletion and death of feeder roots accompany the decline and concluded that root starvation, as a result of crop strain, was the primary cause of tree decline.

Fruit Size

A general decrease in fruit size for all cultivars occurred (Table 3). Beginning in 1972, both Jonathan and Golden Delicious were chemically thinned annually and the high degree of biennial cropping was eliminated. The more consistent and higher annual yields would explain a portion of the general decrease in fruit size. The marked increase in the smaller size 3 fruit in 1974, a year of only moderate crop load (Jonathan 457 bu/a, Golden Delicious 602 bu/a, and Delicious 667 bu/a), was not influenced by fertilizer source or rate. Neither NH_4NO_3 or SCU at the rates used influenced the fruit size distribution of these three cultivars.

In 1972 and 1973, size 4 fruit were included with the culls which explains the relatively large percentage of culls. Russeting, bruising, and color accounted for more than 65% of the culls each year. The fertilizer treatments had no influence on the percentage of fruit culled nor the cullage factor responsible for rejection.

A general overcropping situation existed in all treatments in 1975 which resulted in a significant decrease in large fruit (size 1) and increase in smaller fruit (sizes 3 and 4). The number of fruit per tree was two to three times larger in 1975 than in the other years of the study (Table 4). Neither the nitrogen forms nor the rates of application affected the number of fruit/tree in any year of the study.

Tree Vigor

The rather dramatic reduction in fruit size and low vigor of the trees as indicated by reduced vegetative growth indicated that these trees, particularly the Golden Delicious trees, were not accumulating the quantities of reserves needed for balanced growth and fruiting. Avery (2, 3) reported that similar fruit loads prevented root growth of M 9 to a greater extent than more vigorous rootstocks. He also suggested that some mechanism exists in the most dwarfing stocks that diverts photosynthate into fruit production at the expense of growth in other plant parts. It appears that these mature trees on M 9 rootstocks were directing most of their photosynthates into fruit with little left over to support shoot and root growth. The possibility exists that root foraging was inadequate to take up the soil applied nitrogen. It is

TABLE 3.—Influence of Two Soil Added Nitrogen Sources and Rates on the Fruit Size Distribution of Three Cultivars on M 9 Rootstocks.

Cultivar and Treatment	Rate (lb/Tree)	Fruit Size Distribution* Percent 1972				Percent 1973				Percent 1974					Percent 1975				
		1	2	3	Culls	1	2	3	Culls	1	2	3	4	Culls	1	2	3	4	Culls
Golden Delicious†																			
Check	0	9	34	38	19	23	33	26	18	0	6	85	6	3	1	1	57	25	16
NH_4NO_3	0.5	8	32	43	17	17	35	31	12	1	6	83	6	4	0	2	59	21	18
NH_4NO_3	2.0	13	34	39	14	24	36	27	15	1	6	85	3	5	0	1	50	25	24
SCU 15%	2.0	9	29	47	16	21	36	26	17	1	5	87	4	4	0	1	58	24	16
SCU 30%	2.0	7	33	48	13	20	37	24	18	0	5	86	4	5	0	1	51	27	21
Delicious																			
Check	0	35	26	19	18	31	20	28	20	21	18	48	3	10	2	16	36	14	31
NH_4NO_3	0.5	33	31	16	18	43	17	16	22	36	16	38	2	9	1	11	32	15	42
NH_4NO_3	2.0	29	30	18	15	35	18	19	20	32	15	38	3	12	6	15	32	12	35
SCU 15%	2.0	36	26	21	17	45	15	18	21	35	13	35	2	16	8	19	36	9	27
SCU 30%	2.0	32	31	23	18	40	17	25	21	31	14	32	3	21	5	17	28	12	39
Jonathan																			
Check	0	5	37	49	18	8	45	26	21	6	10	73	1	10	0	20	51	16	13
NH_4NO_3	0.5	5	28	47	16	3	35	36	25	7	12	67	2	12	0	14	54	18	14
NH_4NO_3	2.0	5	29	42	16	6	43	27	25	13	15	58	1	13	0	17	53	15	15
SCU 15%	2.0	7	30	40	19	8	46	22	24	11	16	60	1	12	0	12	54	19	14
SCU 30%	2.0	1	40	42	15	4	41	33	22	6	10	67	2	16	0	12	54	19	14

*Size 1—3 1/8" diameter and larger; size 2—2 7/8"-3 1/16" diameter; size 3—2 5/16"-2 3/4" diameter; size 4—2 1/4" diameter and smaller.
†Trees set 10' x 18', Jonathan planted 1956, Golden Delicious and Delicious planted 1957.

TABLE 4.—Influence of Two Soil Applied Nitrogen Sources and Rates on the Average Number of Fruit per Tree of Three Cultivars on M 9 Rootstocks.

		Average Number of Fruit/Tree											
		Golden Delicions*				Delicious				Jonathan			
Treatment	Rate (lb/Tree)	1972	1973	1974	1975	1972	1973	1974	1975	1972	1973	1974	1975
Check	0	390	205	424	1094	610	385	380	1099	487	420	318	836
NH_4NO_3	0.5	350	195	426	763	608	382	319	1279	339	361	319	872
NH_4NO_3	2.0	518	294	464	1036	616	296	384	875	381	389	339	879
SCU 15%	2.0	367	192	408	855	738	404	356	896	356	332	270	920
SCU 30%	2.0	560	276	398	1044	653	316	385	1128	414	411	346	809

*Trees set 10' x 18', Jonathan planted 1956, Golden Delicious and Delicious planted 1957.

difficult to understand how an application of approximately 290 lb of nitrogen/acre applied under these trees would fail to influence leaf nitrogen content and shoot growth if ample root growth existed for its uptake.

The production efficiency of 600-1,000 bushels per acre achieved by these mature trees on M 9 has been very satisfactory, but the proper balance of growth and fruiting has not been achieved to maintain fruit size. Additional work is needed to determine the leaf to fruit ratio necessary to maintain a balance between root growth, shoot growth, and yield. Such a balance is necessary so that the trees can carry a productive fruit load any given year and still maintain the necessary reserves for adequate shoot, root, and fruit growth the following year.

LITERATURE CITED

1. Anonymous. 1977. Fruit Production Recommendations. Ontario Ministry of Agr. and Food, Pub. 360, p. 61.
2. Avery, D. J. 1969. Comparisons of Fruiting and Deblossomed Maiden Apple Trees, and of Non-fruiting Trees on a Dwarfing and an Invigorated Rootstock. New Phytol., 68:323-326.
3. Avery, D. J. 1970. Effects of Fruiting on the Growth of Apple Trees on Four Rootstock Varieties. New Phytol., 69:19-30.
4. Bukovac, M. J., S. A. Wittwer, and H. B. Tukey. 1958. Effect of Stock-Scion Interrelationships on the Transport of 32p and 45Ca in the Apple. J. Hort. Sci., 33(3):145-152.
5. Ferree, M. E., G. A. Cahoon, and R. G. Hill, Jr. 1973. Fertilizing Fruit Crops. Ohio State Univ., Coop. Ext. Serv., Bull. 458, p. 19.
6. Smith, P. F. 1976. Collapse of 'Murcott' Tangerine Trees. J. Amer. Soc. Hort Sci., 101:23-25.
7. Tukey, R. D., R. Langston, and R. A. Cline. 1962. Influence of Rootstock, Bodystock and Interstock on the Nutrient Content of Apple Foliage. Proc. Amer. Soc. Hort. Sci., 80:73-78.
8. Whitfield, A. B. 1963. The Effect of Stock and Scion on the Mineral Composition of Apple Leaves. Ann. Rept. of East Malling Res. Sta., 4:107-109.

Effects of Postbloom SADH, Urea, Dormant Zinc, and Zinc-Containing Fungicides on Fruit Set and Foliar Nutrient Content in 'Delicious' Apple[1]

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INTRODUCTION

Widespread consumer acceptance of the 'Delicious' apple has stimulated extensive commercial planting of various strains of this cultivar throughout fruit producing regions of the world, including Ohio. Unfortunately, research and grower experience with the 'Delicious' apple has indicated blossoms of this cultivar to be more susceptible than many other cultivars to cold injury, particularly during frost conditions in early spring. In addition, tendencies toward poor fruit set and tardiness in spur and blossom development are disadvantages observed in most 'Delicious' strains, especially the standard, non-spur type strains.

Growth regulators, including SADH-Alar (succinic acid, 2,2-dimethylhydrazide) and ethephon-Ethrel (2 chloroethylphosphonic acid), post-bloom nitrogen (urea), and mechanical scoring of limbs on tree trunks have been observed to induce early flower initiation and, in some cases, promote increased fruit set in various apple cultivars (3, 7, 9).

Nutrient deficiencies, particularly boron (B) and nitrogen (N), have also been implicated in reduced fruit set (2, 8). Post-bloom foliar sprays of nitrogen or boron are now suggested in some fruit producing regions where reduced fruit set can be attributed to a known deficiency.

Severe zinc (Zn) deficiency in fruit crops is known to result in reduced fruit bud development. In recent years, some fruit growers have interpreted this phenomenon to be related to reduced fruit set. Zn deficiency occurs most frequently in soils very high in pH or saline soils in more arid areas.

Diagnosed Zn deficiency in tree fruit crops in Ohio is rare. Most Ohio soils contain sufficient micronutrients including Zn to supply known fruit crop requirements. Only infrequently do specific crop and soil conditions exist under which the Zn level falls below that considered adequate for fruit crops as established by plant analysis. Such conditions may occur in sandy or muck soils, soils high in pH and available phosphorus, and some peat soils. Except for sandy soils, commercial tree fruit crops are usually not established under these conditions. Temporary Zn deficiency may occasionally occur in sandy soils or more often may be induced through mismanagement of nutritional programs, *e.g.*, the excessive application of lime and phosphorus.

If a proven Zn deficiency in a tree fruit crop exists, the most common corrective measure suggested for Ohio has been the application of high concentrations of zinc sulfate as a dormant spray. For maximum response and to avoid leaf and fruit injury, it is suggested the spray be applied just prior to opening of the buds. Recent research indicates, however, that dilute foliar applications of Zn may be more effective than dormant sprays in maintaining satisfactory Zn levels in apple leaves (5).

Application of fungicides containing zinc or manganese (Mn) have also been shown to increase Zn and Mn content of apple tissue (4, 6).

METHODS AND MATERIALS

To assess the influence of Zn, Alar-85, and urea (N) on fruit set in Delicious, a uniform commercial planting of 7-year-old 'Starkspur Supreme' Delicious on seedling rootstock was selected for treatment in spring 1976.

Zn was applied as 22% zinc sulfate at 2.4 kg/100 liters water (20 lb/100 gal) dilute dormant spray on March 3, 1976. Alar-85 at 0.24 kg/100 liters water (2 lb/100 gal) and urea at 0.6 kg/100 liters water (5 lb/100 gal) alone and in combination were applied May 6, 1976, 3 days after full bloom stage of fruit bud development.

Counts of 100 or more blossom clusters on five trees per treatment were made at full bloom, followed by fruit counts on the same limbs in August 1976 to assess fruit set.

No soil application of nitrogen fertilizer was made to this planting in 1976. Treatments were sampled for foliar analysis of N and Zn content, beginning on May 18, 1976, and at approximate 3-week intervals through July 18, 1976.

Unknown to the authors, Dikar fungicide was applied to this planting in a standard recommended spray schedule for Ohio (0.18 kg/100 liters) begin-

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TABLE 1.—Effects of Postbloom Alar, Urea, and Dormant Zinc Applications on Fruit Set, Foliar Nitrogen, and Zinc Content in 'Starkspur Supreme' Delicious on Seedling Rootstock, 1976.

	Nitrogen (%)			Zinc (ppm)†			Mean Fruit
Treatment	5/18	5/26	6/18	5/18	5/26	6/18	Set (%)‡
Urea (5 lb/100 gal)	2 42	2 39	1 97	65	100	124	13 0 a
Zinc Sulfate* (20 lb/100 gal)	2 67	2 54	1 92	55	83	100	9 0 a
Alar (2 lb/100 gal)	2 32	2 37	2 02	56	83	121	18 5 b
Zinc Sulfate* (20 lb/100 gal) + Urea (5 lb/100 gal)	2 53	2 54	2 15	62	95	107	4 5 a
Alar (2 lb/100 gal) + Urea (5 lb/100 gal)	2 49	2 46	2 14	57	101	115	19 6 b
Check	2 64	2 58	2 04	66	107	117	2 0 a

*Zinc and zinc/urea were applied as 22% zinc sulfate in a dormant application on March 2, 1976 Alar and urea were applied on May 6 1976 3 days after full bloom

†Dikar fungicide applied as concentrate spray (6 lb/A) beginning in tight cluster and continuing in succeeding sprays Dikar contains 1 8% zinc expressed as 1 8% Zn^{++} and 14 4% manganese expressed as Mn^{++} ions

‡Mean fruit set based on number of fruit per 100 or more blossom clusters, five trees per treatment Means followed by same letter not significantly different at 5% level (Duncan's multiple range)

ning at tight cluster stage, for control of apple scab (*Venturia inequalis*) and powdery mildew (*Podosphaera leucotricha*). Dikar is a special formulation of mancozeb (Dithane M-45) and dinocap (Karathane) and contains 1.8% zinc, expressed as Zn^{++} ion, and 14.4% manganese as Mn^{++} ion

Because of the complicating influence of Zn applied through the Dikar fungicide application in this test, an additional test was established in 1977 to examine the influence of two fungicides containing Zn and manganese (Mn) on foliar content of these micronutrients. Dikar and Dithane M-45, a coordination product of zinc ion (2% Zn^{++}) and manganese ethylene bisdithiocarbamate (16% Mn^{++}), were applied on April 29, 1977, 7 days after full bloom, to 21-year-old 'Starkrimson' Delicious trees at the Lane Avenue Horticultural Farm in Columbus. Five trees each were treated with Dikar at 0.18 kg/100 liters water (1.5 lb/100 gal) or Dithane M-45 at 0.18 kg/100 liters water (1 5 lb/100 gal) as a dilute spray. Fully developed leaves from spurs on 2 and 3-year-old tissue were sampled on May 11 and Sept. 2, 1977, for foliar analysis. Immediately after sampling, both check and treated leaves were washed with detergent followed by 0.1 N HC1 wash and rinsed in distilled water to remove external zinc and manganese prior to analysis, as described by Ashby (1).

All fruit was lost to a severe freeze on the night of April 29, 1977. Trees in this test received no additional pesticide applications during the 1977 season following initial treatment.

In the 1976 test, foliar application of urea had little apparent influence on leaf N content sampled May 18, 12 days after application (Table 1). Differences were consistent with normal variation observed in single samples between treatments. In all treatments, early season foliar N levels were above those considered adequate for fruit set in Delicious. As normally occurs, leaf N declined through the end of the active period of shoot growth in mid to late July in Ohio.

Similarly, Zn levels in foliage were unusually high in all treatments. Zn levels in foliage increased in all treatments through the sampling period to levels considered very high in normal foliar sampling in Ohio commercial apple orchards. Very high Zn undoubtedly resulted in part from surface Zn residues following Dikar fungicide applications for the season.

Higher Zn content, either through dormant Zn, combined Zn/urea, or from Dikar applications in the check did not result in increased fruit set. Urea application alone did not significantly increase fruit set. Increased fruit set occurred only in Alar or in combination Alar/urea treatments, and is generally con-

TABLE 2.—Early and Late Season Foliar Zinc and Manganese Content in 'Starkrimson' Delicious Following a Single Application of Dikar or Dithane M-45 Fungicides.*

	Zinc (ppm)		Manganese (ppm)	
Treatment†	5/11/77	9/2/77	5/11/77	9/2/77
Check	33	38	21	13
Dikar (1 5 lb/100 gal)	68	63	200	25
Dithane M-45 (1 5 lb/100 gal)	115	42	194	37

*Dikar (1 8% Zn^{++}, 14 4% Mn^{++}) and Dithane M-45 (2 0% Zn^{++}, 16% Mn^{++}) applied April 29, 1977, 7 days after full bloom All fruit was lost to a freeze on the night of April 29 No additional pesticides applied in 1977

†Foliage washed in detergent followed by 0 1 N HCl wash and distilled water rinse to remove surface residual Zn and Mn deposits.

sistent with results obtained in previous tests with post-bloom Alar applications (7).

Results of the single application treatment of fungicides containing Zn and Mn in the 1977 test indicated a substantial increase in content of these micronutrients at both early and late season sampling dates (Table 2) when compared with untreated trees. Both Zn and Mn content were within levels considered sufficient to high for apples in Ohio.

Regrettably, evaluation of the influence of Zn and Mn applied through fungicides on fruit set was not possible in the 1977 test. Where fruit was present in the 1976 test, however, Zn levels apparently were similar to 1977 tests and indicate that fungicides containing Zn applied early in the season can supply adequate zinc for tree requirements In fact, it is likely that foliar application of Zn through Zn containing fungicides or dilute foliar applications of zinc sulfate in the early post-bloom period are as effective as a separate dormant application of zinc sulfate in providing Zn for apple tree requirements. Zinc application is not recommended on apples in Ohio except in the rare instances where severe deficiency is determined through foliar analysis.

LITERATURE CITED

1. Ashby, D. L. 1969. Washing Techniques for the Removal of Nutrient Element Deposits from the Surface of Apple, Cherry and Peach Leaves. J. Amer. Soc. Hort. Sci., 94:266-268.
2. Boynton, D. and E. G. Fisher. 1949. Results of Use of Urea Sprayed on Foliage. Proc. N. Y. Hort. Soc., 94:101-103.
3. Dennis, F. G., Jr. 1968. Growth and Flowering Responses of Apple and Pear Seedlings to Growth Retardants and Scoring. Proc. Amer. Soc. Hort. Sci., 93:53-61.
4. Mason, J L., R. P. Gardiner, and P. C. Sanderson. 1972 Dimethyldithiocarbamate Sprays of Zinc, Iron and Manganese as a Nutrient Source for Apple Trees. Can. J. Plant Sci , 52:110-111.
5. Orphanos, P. I 1975. Spray Application of Zinc to Young Apple Trees. Hort. Res., 15(1): 23-30.
6. Ross, R. G. and D. H. Webster. 1976. Effect of Fungicides on the Nutrient Content of Apple Leaves. Can. J. Plant Sci., 56:1001-1002.
7. Stang, E. J., D. C. Ferree, and F. R. Hall. 1976. Effects of Scoring and Growth Regulators on Flower Initiation, Fruit Set, and Aphid Populations in Young Apple Trees. Ohio Agri. Res. and Dev. Center, Res. Circ. 220, pp. 9-13.
8. Thompson, A. H. and L. P. Batjer. 1950. The Effect of Boron in the Germinating Medium on Pollen Germination and Pollen Tube Growth for Several Deciduous Trees. Proc. Amer. Soc. Hort. Sci., 56:227-230.
9. Williams, M. W. 1972. Induction of Spur and Flower Bud Formation in Young Apple Trees with Chemical Growth Retardants. J. Amer. Soc. Hort. Sci., 97:210-212.

Economic Appraisal of Insect and Disease Injury to Ohio Peaches and Potential Pesticide Use Strategies

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INTRODUCTION

The detailed appraisal of insect and disease injury in the format of a life table has yielded valuable information on bioeconomics of apple pests (10). Need for pesticides in high value crops such as peaches is well known, yet little information has been collected on economic losses caused by insects and diseases.

Harcourt (12) constructed a life table for a vegetable crop and related its usefulness to development of practical pest management options. The author modified this technique to illustrate impact of insects and diseases on apple quality and yields and noted the lack of defined economic incentives to assist a change to optimal pesticide use policies on high value crops (10). This report is an economic appraisal of crop injury by both insects and diseases to four varieties of peaches.

METHODS AND MATERIALS

Studies were initiated in 1971 at the Ohio Agricultural Research and Development Center, Wooster. The study area consisted of a 1-acre block containing ca. 20 replicates of 'Halehaven', 'Golden Jubilee', 'Elberta', and 'Cumberland' peach varieties planted in a 25 x 25 ft grid in 1964 and maintained in a sod culture.

Prior to the study, trees were sprayed each year with insecticides and fungicides on a regular schedule. During the study years, the block was fertilized and mowed but pesticides were omitted. An unsprayed block of plums was immediately north and unsprayed blocks of apples immediately south and west of the study area.

SAMPLING

During May 1971, 2-4 limbs/tree were tagged (10-15 trees/variety) and the fruits were examined *in situ* at various intervals throughout the growing season. The experiment was initially established as a crop life study with data recorded at 7-10 day intervals. Assessment of damage to individual fruits was completed twice in June and July and at harvest. Sampling was initiated shortly after shuck-split each year. No estimates were made of insect or disease damage to peach foliage, twigs, limbs, or trunks.

Loss of individual fruits was recorded as insect or disease injury on the fruit which, if graded according to USDA and Ohio grade laws, would result in that fruit being classified as nonsaleable fresh fruit or "cull". Each type of injury was recorded separately but multiple "hits" by the same insect or disease on an individual fruit were recorded as a single cull factor. Each identified insect or disease which caused injury to an individual fruit was designated as a cull factor.

In the first year of the study, there was a full crop and no pesticides were used on the block. Hand thinning was required on all varieties. Severe winter conditions in 1972 killed most peach buds, precluding data acquisition. A mild winter in 1973 with a severe drop in temperatures in February resulted in a complete loss of all peach buds. Severe winter conditions thinned peach buds in 1974, resulting in ca. 33% crop, but a sampling program similar to that conducted in 1971 was initiated.

A good crop of peaches was produced in 1975 (75% of full). Following 4 years with no pesticides (1971-1974), ca. one-half of the block was placed back on a chemical protection program. Azinphosmethyl plus captan at 0.75 lb AI and 1.75 lb AI/acre, respectively, were utilized in a standard spray schedule. Fruit injury from pests was rated at harvest.

To ascertain the economic impact of various cull factors, average market prices were obtained for Ohio peaches in 1971 and 1974. The average prices were based on yields of 200 bu/acre graded to U. S. No. 1 and priced at \$6.00/bu and \$8.00/bu in 1971 and 1974, respectively. Analyses included the dollar loss per acre for each cull factor as well as the total effect on both yield and quality by all crop injury factors for each variety throughout each season. No attempt was made to present net income, but merely potential for gross income.

RESULTS AND DISCUSSION

Economic Appraisal

As noted in a previous study (9), the format of this life table differs from the conventional insect life table in that it records each mortality (cull factor) on each individual fruit. The study was terminated at harvest and the potential yield was initially determined using the number of fruits present at shuck-split stage as the base. For example, Table 1 presents a typical analysis of crop injury occurring on the Cumberland variety in 1974. This tabulation

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[2]Thanks are expressed to Dr. Robert A. Spotts, Dept. of Plant Pathology, for his review and critical comments of this manuscript and to John Gregory for technical assistance.

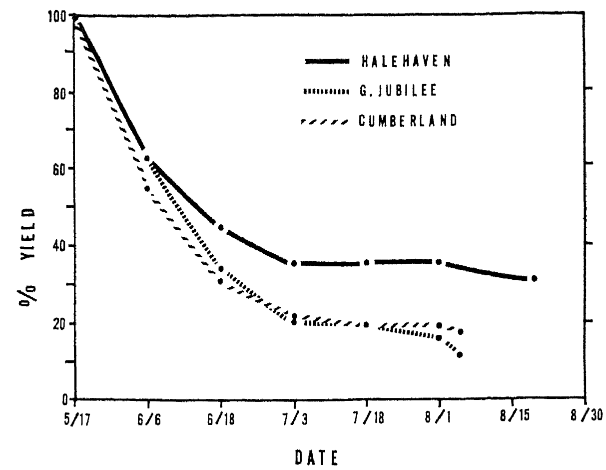

FIG. 1.—Effects of insect and disease injury on potential yield of three varieties of peaches, Wooster, 1974.

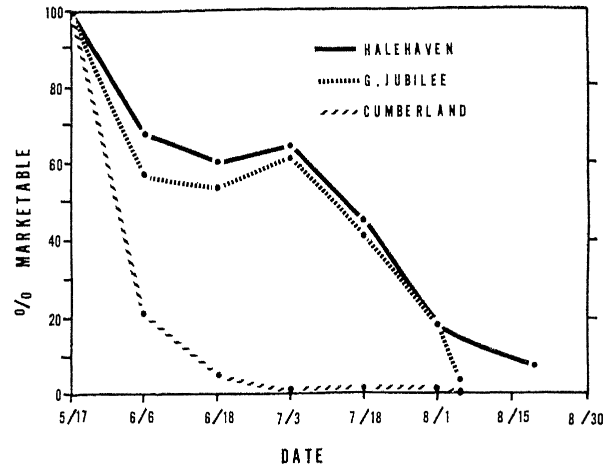

FIG. 2.—Effects of insect and disease injury on quality of three varieties of peaches, Wooster, 1974.

allows an appraisal of the relative importance of each cull factor in relation to those fruits remaining at specific sampling dates. Each factor could be severe enough to cause the fruit to be unsaleable as a U. S. No. 1 fruit. The degree of economic loss resulting from multiple injuries to the same fruit as well as relative varietal susceptibility can be determined within each sampling period.

The recording of multiple injuries (Table 1) served to illustrate the complexity of damage potentials from a number of fruit insects and diseases. Only ca. 22% of the fruits were potentially marketable in early June when the sum of individual cull factors greatly exceeded the total number of fruits in the plot. Within 30 to 50 days after shuck-split, major peach damage was caused by the plant/stink

TABLE 1.—Crop Injury Development on Cumberland Variety, Wooster, 1974.

Sample Date	Total Fruits per Plot	Total Fruits Marketable per Plot	Major Cull Factors	Total Cull Factors per Plot	Percent Cull
June 6	309	67	Plant/Stink Bug	178	57.6
			Oriental Fruit Moth	4	1.3
			Rusty Spot	188	60.8
				370	
June 18	177	9	Plant/Stink Bug	65	36.7
			Oriental Fruit Moth	5	2.8
			Rusty Spot	166	93.8
				239	
July 3	123	2	Plant/Stink Bug	41	33.3
			Oriental Fruit Moth	2	1.6
			Rusty Spot	121	98.4
				164	
July 18	110	0	Plant/Stink Bug	46	41.8
			Oriental Fruit Moth	1	0.9
			Plum Curculio	4	3.6
			Rusty Spot	110	100.0
			Peach Scab	10	9.1
				171	
August 5 (Harvest)	99	0	Plant/Stink Bug	48	48.5
			Plum Curculio	32	32.3
			Japanese Beetle	1	1.0
			Rusty Spot	99	100.0
			Peach Scab	25	25.3
				205	

bug complex. Severe infection of the Cumberland variety by the apple powdery mildew fungus, *Podosphacra* sp. (8), was noted in early June. The development of peach scab, *Cladosporium carpophilum* Thuem., was observed in mid-July.

Figures 1 and 2 show the development of total fruit injury caused by insects and diseases and their influence on yield and quality of three varieties in 1974 when no hand thinning of fruits was required. All injury factors were determined as a percentage of the potential yield at shuck-split stage of fruit development (ca. May 17). Yields of all three varieties were reduced to less than 50% of potential yield within ca. 30 days of shuck-split (Fig. 1). Of the remaining fruits, only ca. 20% of Cumberland fruits were marketable on June 6; Halehaven and Golden Jubilee remained above 50% marketable until well into July (Fig. 2).

Maximum dollar losses by variety from each major cull factor for 1971 and 1974 are presented in Table 2. In 1971, the reduction in income ranged from 33% (Golden Jubilee) to 91% (Cumberland). During the first year without pesticides, major injury to fruit in the form of cat-facing by tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), scarring and gumming by the hickory plant bug, *Lygocoris caryae* (Knight), water-soaked injury by *L. quercalbae* Knight, and gummosis probably caused by *L. omniragus* Knight appeared in ca. the same seasonal sequence as observed by Rings (17).

The potential income per acre was higher for the partial crop in 1974 but the loss in income at harvest increased to a fraction of potential income on all varieties (Table 2). The Cumberland variety had more than $2,700 loss on a crop with a potential income of $1,600 due to the cumulative effect of major cull factors.

Although plant bug injury was lower than in 1971, damage from plum curculio was much higher in 1974. Disease incidence had reached the point where almost all Golden Jubilee peaches were lost to peach scab and 100% of Cumberland peaches to rusty spot. Elberta was again reduced by a frost-freeze. While not recorded, there was a marked increase in the severity of peach leaf curl, *Taphrina deformans* (Berk.) Tul., which undoubtedly contributed to some weak buds and subsequent fruit drop. In addition, flagging of terminals caused by Oriental fruit moth larvae was very high in 1974.

Incidence of brown rot, *Monilinia fructicola* (Wintr.) Hoovey, during bloom stage was minimal throughout the study years. Chandler (1974) observed the same in his studies. Although lack of significant injury from brown rot may have been due to erratic cropping, brown rot is particularly devastating in humid climates and during storage and shipping. A more accurate estimate of brown rot incidence undoubtedly would have been made if fruits had been harvested and stored at room temperature for several days.

In 1975, following 4 years of no pesticides, applications of azinphosmethyl reduced plum curculio damage 87% while Oriental fruit moth damage was reduced 90% (Table 3). The Elberta peach crop was again reduced by low temperatures to <1% of the Cumberland crop. "Control" fruits which were harvested and held at room temperatures for 7 days developed 75-100% infection by brown rot which was particularly heavy where fruits were also injured by insects. The amount of plant/stink bug damage, although reduced in this first year of pesticide protection, was still unacceptable for commercial orchards.

By 1976, the percent damage caused by plum curculio and Oriental fruit moth had been reduced to

TABLE 2.—Maximum Dollar Loss by Major Cull Factors on Peaches from Untreated Trees, Wooster, 1971 and 1974.*

Variety	Potential $/Acre	Income $/Acre Harvest	Plant Bugs†	Plum Curculio	Other Insects‡	Rusty Spot	Peach Scab	Brown Rot
					1971			
Halehaven	1,200	432	900	12	120	144	12	72
Golden Jubilee	1,200	804	600	0	84	0	0	12
Elberta	1,200	576	900	432	48	12	12	36
Cumberland	1,200	108	384	60	300	1,092	72	0
					1974			
Halehaven	1,600	96	208	1,072	26	48	1,216	80
Golden Jubilee	1,600	64	224	528	296	64	1,360	2
Elberta	1,600				Frost—No Fruit			
Cumberland	1,600	0	160	512	120	1,600	400	48

*Peach crop for 1972 and 1973 was frozen—0 $ income at harvest.
†Includes tarnished plant bug, **Lygus lineolaris** (Palisot de Beauvois), hickory plant bug, **Lygocoris caryae** (Knight), **quercalbae** Knight, and **omniragus** Knight.
‡Includes Japanese beetle, **Popillia japonica** Newman, and Oriental fruit moth, **Grapholitha molesta** (Busck).

TABLE 3.—Control of Peach Pests with a Regular Spray Program Following 4 Years of Pesticide Absence, Wooster, 1975.*

Treatment	Plum Curculio	Oriental Fruit Moth	Plant/Stink Bug	Brown Rot	Peach Scab	Rusty Spot
		Golden Jubilee				
Check	4	21	31	5	85	0
Azinphosmethyl plus Captan Standard	0	0	11	0	17	0
		Cumberland				
Check	3	2	21	0	8	98
Standard	0.4	1	7	0.1	2	97
		Halehaven				
Check	8	37	28	21	3	42
Standard	2	5	14	14	1	8

*Five trees of each variety.
†All fruit from each replicate tree rated at harvest, 965-1776 total fruits.

less than 0.2% each compared to 77% and 48% damage in the checks. However, in 1977 a severe spring freeze once again eliminated the gathering of additional data from this orchard.

Pesticide Strategies

Marketing goals play a major role in pest control decisions by fruit growers. Hall (11) reported that 43% of respondents in a grower survey marketed one-half or more of their crop via a farm market while 25% and 15%, respectively, noted they sent one-half or more of their crop to wholesale and retail markets. Processing firms or farm cooperatives were not major outlets for their fruits. PYO (pick-your-own) operations and farm stands can be somewhat insulated from large scale price fluctuations, but consumers object to substandard quality fruits. In years of above average production, fruits of lesser quality are essentially non-saleable as fresh produce.

External quality of peaches relates directly to product shelf life. Insect injury to peaches can be potential entry points for brown rot (3). In addition, all marketing trends indicate an increase in quality standards, particularly for fresh produce. These consumer constraints play a major role in grower risk aversion observed in high value crops such as peaches. Thus, the recent report (1) which stated that little change is expected in pesticide use patterns on apples (preventing rather than curative) may also apply to peaches and other tree fruits in the absence of practical alternatives where a complex of pests is present in the orchard.

Economic analyses to improve decisions concerning environmental effects of pest control strategies along with estimates of biological uncertainties should aid good decision making (5, 14). Headley (14) also suggested that the economic threshold should vary with the price of the produce. Unfortunately, prices for peaches have typically undergone large year-to-year fluctuations, generally brought about by crop failures due to frost-freeze. The uncertainty of weather is a major factor in the current use of protective spraying in tree fruits.

Experience in mid-Ohio over the last 10 years shows very few years with a maximum peach crop (Table 4). In addition, a recent survey of Ohio growers by Hartman (13) revealed that the three leading problems in peach production were considered to be low winter temperature injury, spring freezes, and canker-borer problems. While all three affect fruit production, the third group more typically appears on weakened and stressed trees. Hartman (13) also found that 46% of the growers were cropping *less* than 2 years out of 5 and only 15% *more* than 4 years out of 5.

Peach industry officials recently reported that the industry has been declining and financial support for research on these problems looks very dim (2). Increased federal regulations and the potential for

TABLE 4.—Peach Crop Histories in Selected Mid-Ohio Orchards, 1965-1975.

Ohio Locations	Type	Years of Record	Cropping Probabilities: None	33-50%	Full
Wooster	OARDC Research	1971-1975	0.4	0.4	0.2
Wooster	Small Commercial	1965-1975	0.6	0.2	0.2
Jeromesville	Commercial PYO	1965-1975	0.3	0.3	0.4
Salem-NW	OARDC Branch Research	1970-1975	0.5	0.3	0.2

RPAR's (rebuttable presumptions against registration) being placed on EDBC and benomyl add to the problems faced by the peach industry. Under these situations, the decision-making process becomes even more difficult with stone fruits which require 4-6 years to obtain a return on investment (ROI). These zero production years may not necessarily coincide with either a state or U. S. short crop which, based on historical supply/demand relationships, dictates higher product prices.

In perspective, it is obvious that when cropping peaches in only 2 of 5 years, risking insect or disease injury when a full crop is finally produced is not a viable alternative to most growers. Price leve's are not generally established before the critical pesticide time period develops, *i.e.,* 30-40 days after bloom. Not only is ROI a major problem with tree crops (4), but marketing situations involving long range customer-producer relationships and quality produce are not likely to be altered on the basis of the probable saving of some costs of pesticides. This saving in the form of reduced numbers of sprays may be offset by increased amounts of disease as well as increased grading expenditures (7).

The average Ohio grower has other crops such as apples, plums, pears, cherries, corn, vegetables, grapes, or strawberries (11). This diversity of crops, while offering insulation to severe weather or changes in cropping potential and subsequent income, also presents some management problems. PYO strawberries and many berry crops, for example, are near harvest dates when peaches are at the stage where certain adjustments can be made in pesticide applications.

While there is low confidence in prediction of U. S. or even Ohio production of peaches, there would seem to be opportunities to reduce major economic injury occurring in the 30-day period immediately following bloom. Plum curculio damage was noted to range from relatively low levels to quite high levels during this study and apparently responds to annual weather changes as also reported by Chandler (6).

If two applications of azinphosmethyl were applied at 0.5 lb AI/100 gal for the control of plum curculio only (based on injury levels in Table 2), at a cost of ca. $7.20/acre, and were 85% successful, a cost-benefit ratio from 0 to ca. 50:1 would have been obtained in 1971. The cost-benefit ratio in 1974 would have ranged from 0 to 120:1. Other costs resulting from direct damage or loss of fruit, as well as unmeasured indirect damage from increased labor requirements for sorting damaged fruit, would reduce the benefit ratio. Sampling for adult movement and refinement of host plant attraction relationships could substantially aid the more accurate placement of specific chemicals for control of plum curculio.

Although little can be done about sampling for the plant bug complex, planting away from wooded areas and practicing weed control can reduce pressures from these insects (17). Spraying for plum curculio is also recommended during the same time the major effects of these insect pests occur.

The relationship between the numbers of flagged terminals and Oriental fruit moth populations, especially during August and September, could aid prediction of larval entrances on late varieties. Pheromone traps may promote the same predictive capability at less cost. The establishment of visual threshold injury levels for insect pests, which are helpful guidelines for economic damage and subsequent actions, are of more limited value in the case of certain peach diseases. For example, 40-70 days elapse from the time the spores of *C. carpophilum* Thuem. land on the fruits until the symptoms of peach scab are visible (15). However, good control of apple powdery mildew in nearby apple orchards should decrease the potential for rusty spot (8).

The cropping probability in some peach growing areas and the risk aversion associated with the potential economic losses observed in this study would seem to preclude severe reductions in current pesticide use on peaches. This is particularly true in the absence of significant changes in current consumer demands for quality produce and state and federal grade laws on high value crops. Quality and quantity of fresh fruit are major economic factors governing net income to growers. Improvements in cultural practices to increase yield and quality of the packout, as well as precise application of pesticides as noted by Ferree and Hall (9) for apples and by Phillips and Weaver (16) for peaches, can offer substantial benefits with a minimum of risk.

Additional information concerning the levels of insect populations associated with damage thresholds should increase grower confidence in predicting chances of success when making adjustments in pesticide strategies. However, the Ohio peach grower presently lacks such information and is likely to choose the conventional approach to pesticide usage in order to yield (what appears to him) the maximum ROI whenever he has a crop.

LITERATURE CITED

1. Anonymous. July 1975. A Study of the Efficiency of the Use of Pesticides in Agriculture. Midwest Research Institute Report for Environmental Protection Agency, Vol. I, 124 pp.
2. Anonymous. Jan. 1978. Peach Industry at the Crossroads. Amer. Fruit Grower, pp. 13-14.

3. Brann, J. L., P. A. Arneson, and G. N. Oberly. 1975. Tree-fruit Production Recommendations. N. Y. State College of Agr. and Life Sciences, 48 pp.
4. Cain, T. C. 1969. Tree Spacing in Relation to Orchard Production Efficiency. N. Y. State Agri. Exp. Sta., Res. Circ. 15, 10 pp.
5. Carlson, G. A. 1970. A Decision Theoretic Approach to Crop Disease Prediction and Control. Am. J. Agri. Econ., 52:216-223.
6. Chandler, S. C. 1958. Plum Curculio Populations in an Unsprayed Peach Orchard in Northern Illinois. J. Econ. Entomol., 51:330-332.
7. Chandler, W. A. 1974. Control of Peach Disease with Benomyl in Full and Modified Schedules. Hort. Sci., 9:332-333.
8. Daines, R. and J. Trout. 1977. Incidence of Rusty Spot of Peach as Influenced by Proximity to Apple Trees. Plant Disease Reporter, 61:835-836.
9. Ferree, D. C. and F. R. Hall. 1974. Fruit Quality Factors in Dwarf Apple Trees. OARDC, Ohio Report, 59:61-63.
10. Hall, F. R. 1974. Bioeconomics of Apple Pests: Cost Appraisal of Crop Injury Data. J. Econ. Entomol., 67:517-521.
11. Hall, F. R. 1977. Survey Shows How Ohio Fruit Growers Use Orchard Pesticides. OARDC, Ohio Report, 62:35-37.
12. Harcourt, D. G. 1970. Crop Life Tables as a Pest Management Tool. Can. Entomol., 102:950-955.
13. Hartman, F. O. 1978. Peach Hardiness from the Grower's Point of View. Ohio Hort. Soc. Proceedings, in press.
14. Headley, J. C. 1972. Defining the Economic Threshold. *In* Nat. Acad. Sci., Pest Control Strategies for the Future, Washington, D. C., pp. 100-108.
1973. Environmental Quality and the Economics of Agricultural Pest Control. EPPO Bull., 3:51-61.
15. Jones, A. L. 1971. Diseases of Tree Fruits in Michigan. Mich. State Univ., Coop. Ext. Serv., Bull. E-714, 31 pp.
16. Phillips, J. H. and G. M. Weaver. 1975. A High-density Peach Orchard. Hort. Sci., 10: 580-582.
17. Rings, R. W. 1958. Types and Seasonal Incidence of Plant Bug Injury to Peaches. J. Econ. Entomol., 51:27-32.

Effects of Air Volume Rate and Travel Speed on Air Velocities Delivered by Orchard Air Sprayers

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SUMMARY

Air velocities produced by orchard air sprayers decreased as travel speed increased and always diminished rapidly with increasing distance from the outlet. However, decreases in air velocity were at lower rates for sprayers which delivered high mass flows than they were for sprayers which delivered low mass flows.

INTRODUCTION

Both the deposition efficiency and distribution of chemicals applied by air sprayers are far from ideal. Steiner (8) found only 70% of the applied material deposited on apple trees when spraying 561 l/ha (60 gpa) of solution and only 55% deposited when spraying 3741 l/ha (400 gpa) during nearly ideal conditions. Hall *et al.* (3) measured deposits of Guthion at various sample sites in apple trees. The high and low-airflow-rate sprayers, respectively, deposited 2.1 and 8.9 times more residue on the sites nearest the sprayers than in the tops of the trees. In another experiment, Hall *et al.* (2) reported consistently higher amounts of fruit scab in the tops of apple trees that were sprayed with air sprayers.

With the trend toward increasing costs for chemicals and toward increasing concern for environmental protection, improvement in deposition efficiency and distribution is essential.

Air sprayers rely on the air streams, or jets, they deliver to put the spray on target. The air stream must be strong enough to drive the spray into the tree and impinge the drops onto the foliage. Since it is often necessary to spray when the wind is not calm, the air jet should be effective in light winds. Further, it is desirable to use the minimum air horsepower needed to deliver the spray on target.

To make appreciable improvements in air sprayers, one must know how their air jets are affected by operating conditions. The objective of this study was to measure air-velocity profiles at various horizontal distances from orchard air sprayers under several combinations of air velocity, mass-flow rate, and ground-travel speed.

EQUIPMENT AND PROCEDURE

Air velocities produced by sprayers were measured at five levels in an open field, and at the centers and far sides of two trees in a peach orchard. In the open field, measurements were made at heights of 1.46, 2.67, 3.55, 4.43, and 5.59 m above ground. In the orchard, velocities were measured at 1.24, 2.45, 3.33, 4.22, and 5.59 m heights. Measurements in the center and on the far side of the trees were made when the air outlets traveled lines which were a horizontal distance of 3.1 and 4.6 m, respectively, from the sensors. Measurements in the open were made with the horizontal distances of 1.5, 3.1, and 4.6 m between the path of the outlet and the anemometer sensors. At least six passes were made with the sprayer at each of the travel speeds of about 3.7, 5.0, and 8.0 km/h. The background wind velocities were measured at all heights both before and after the sprayers passed the measurement station.

The three orchard air sprayers used in the experiment were considerably different. The model 2A36[4,5] (Fig. 1) sprayer has its own engine, which drives two 0.91 diam axial flow fans that deliver about 33.0 m^3/s of air at 113 km/h. The model 803S[5] (Fig. 2) sprayer is powered by a tractor PTO shaft and has a centrifugal fan. The width of the outlet on the sprayer can be adjusted from 5.7 to 11.4 cm wide. When the outlet is completely open, the 803S will deliver about 11.2 m^3/s of air at 167 km/h. During these experiments, the outlet width was set at either 7.0 or 9.5 cm. At the 7.0 cm wide opening, the 803S delivers about 7.2 m^3/s of air at 177 km/h. It discharged about 9.8 m^3/s of air at 177 km/h when the outlet was 9.5 cm wide. The model 3P50[6] (Fig. 3) sprayer is mounted on a three-point hitch and powered by the tractor PTO shaft. This sprayer also has a centrifugal fan which delivers about 1.8 m^3/s of air at 322 km/h.

The 2A36 and 803S sprayers discharge air from both sides of the sprayer so two rows of trees can be sprayed simultaneously. The air outlets on the 3P50 sprayer can also be rotated to discharge air from both sides of the sprayer, but were set to discharge air from only one side of the sprayer during these experiments. The 2A36, 803S, and 3P50 sprayers will be designated as high-airflow-rate (mass) (HAFR), me-

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[4]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U. S. Dept. of Agriculture and does not imply its approval to the exclusion of other products which may be suitable.

[5]Manufactured by F. E. Myers & Bros. Co., Ashland, Ohio.

[6]Manufactured by De Kinkelder, Zevenaar, Holland.

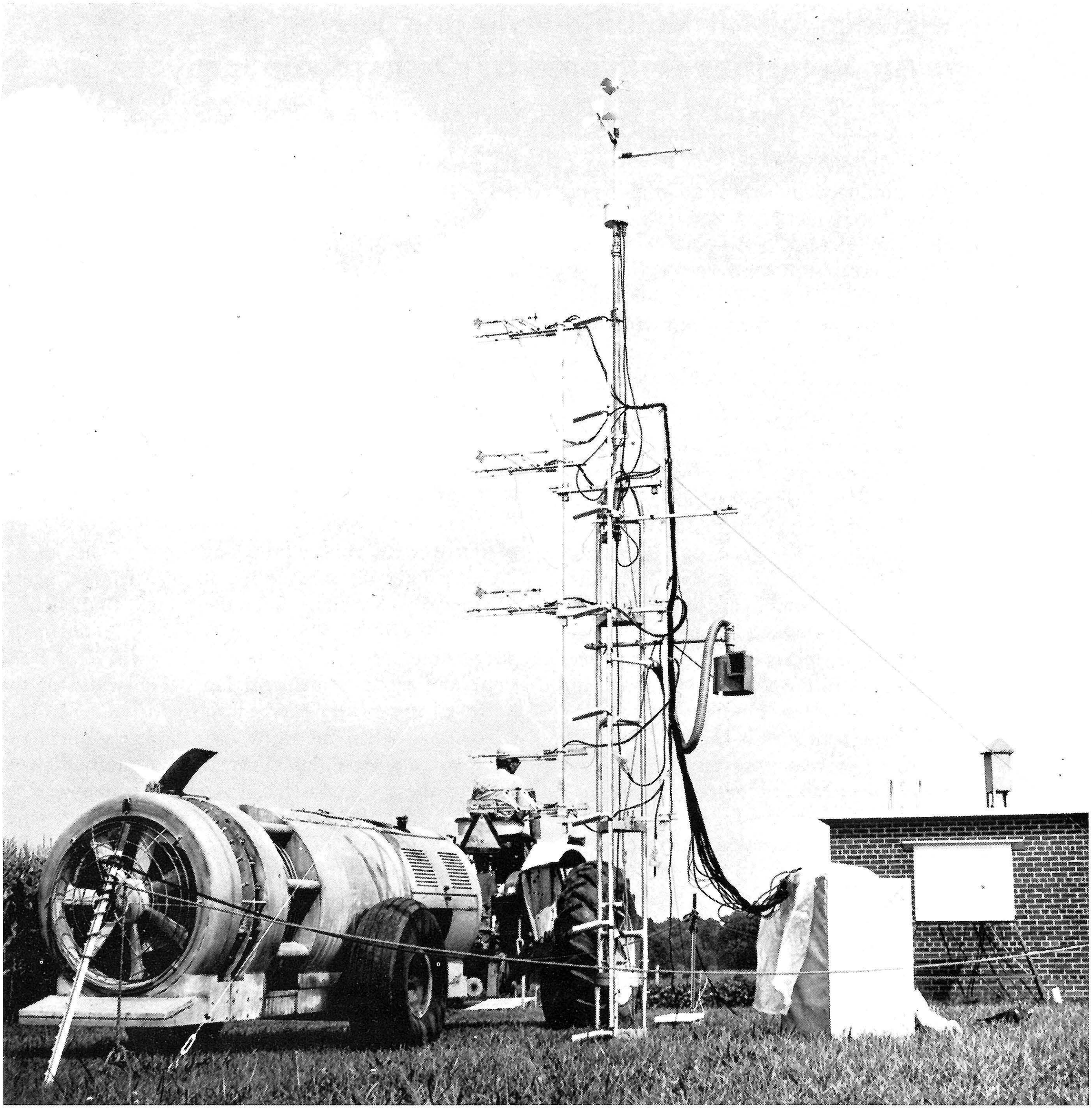

FIG. 1.—2A36 sprayer and tower with anemometer and direction sensors.

FIG. 2.—803S sprayer.

dium-airflow rate (MAFR), and low-airflow-rate (LAFR) sprayers, respectively.

The air velocities were measured at the lower levels with hot-film anemometer sensors and at the top level with a Gill UVW propeller anemometer. It was possible to measure all three mutually perpendicular velocity components at each level. The air velocity, wind direction, and travel-timing signals were recorded on magnetic tape. Detailed information on the data acquisition and processing components used in these experiments are included in a paper by Fox *et al.* (1).

Air velocity data were processed with a model 960A Texas Instruments minicomputer. The computer program calculated the following: component and resultant sprayer air velocities; means and standard deviations for the component and resultant velocities; distance from the starting point to maximum velocity for the three component velocities and the resultant velocity; sprayer travel speed between starting and stopping points; and means for the component and resultant atmospheric wind velocities.

Formulas have been developed for air velocities delivered by stationary nozzles in laboratories and wind tunnels, but none are known to apply directly to jets from moving air sprayers. Multiple regression analyses were used to develop air velocity equations from data for each sprayer. The dependent variable was maximum resultant air velocity. For

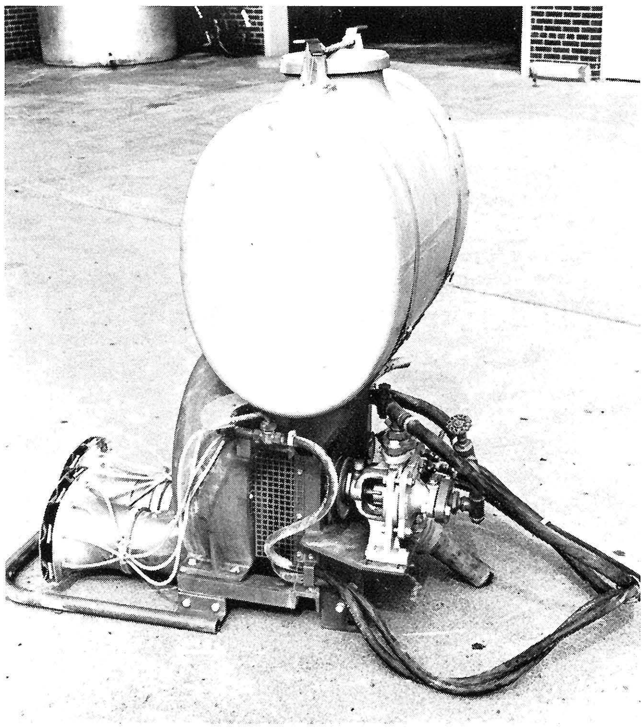

FIG. 3.—3P50 sprayer.

measurements in the open, the independent variables were: sprayer travel speed, horizontal distance between the air outlet and anemometer sensors, and height of the sensors above ground. The independent variables for the orchard data were travel speed and height above ground.

The multiple regression analyses showed highly significant influence for horizontal and vertical (height) distance and for ground travel speed. The multiple correlation coefficient was lowest for the LAFR sprayer, probably because it delivered very low velocities with increasing height and horizontal distance from the outlet. Although wind velocities were very low during the experiment, the wind affected the jet from the LAFR sprayer more than the jets from the other sprayers. The paper by Reichard *et al.* (7) gives detailed results of the regression analyses.

Figures 4, 5, and 6 are plots of air velocities computed from regression equations for the HAFR, MAFR with 9.5 cm (3.75 in) outlet opening, and LAFR sprayers, respectively. The figures show the effects of travel speeds (4, 6, 8 km/h) and horizontal distances from the air outlets on the air velocities delivered at 3.35 m above ground. A plot of the same variables for the MAFR (7.0) sprayer would show curves similar to those in Fig. 5, but lower in velocity, for each of the three speeds. Figures 4 and 5 show that an increase in either the travel speed or horizontal distance from the sprayer outlet decreased the air velocity delivered. Figure 6 (LAFR sprayer) shows that an increase in horizontal distance decreased the air velocity delivered, but the effect from changes in travel speed is less clear than for the other sprayers. The lack of effect from changes in travel speed was probably due to the very low air velocities delivered by the LAFR sprayer at greater horizontal and vertical distances.

Figure 7 shows a comparison of the air velocities delivered at 3.35 m height by the HAFR(2A36),

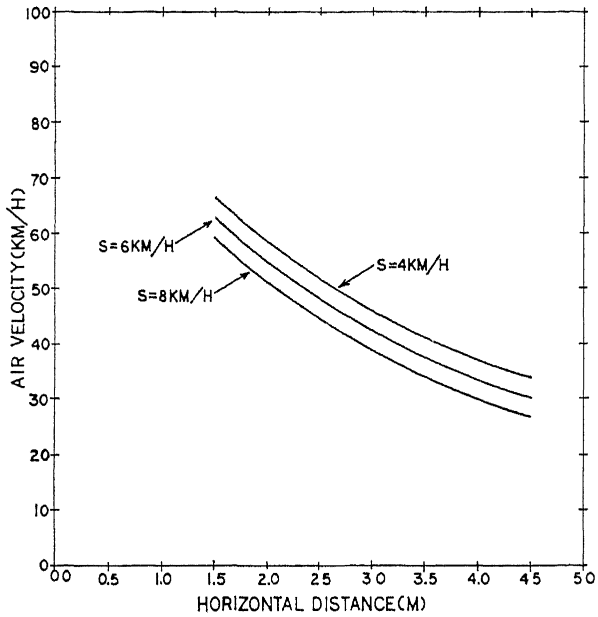

FIG. 4.—Effect of travel speed and horizontal distance from air outlet on air velocity delivered at 3.35 m height by HAFR sprayer.

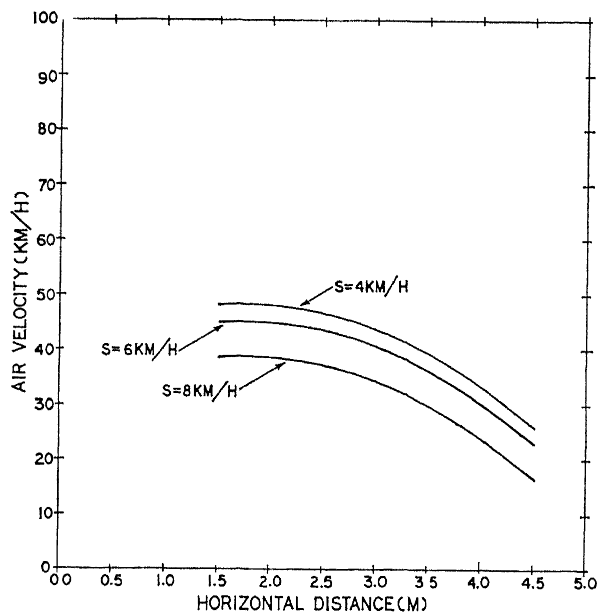

FIG. 5.—Effect of travel speed and horizontal distance from air outlet on air velocity delivered at 3.35 m height by MAFR(9.53) sprayer.

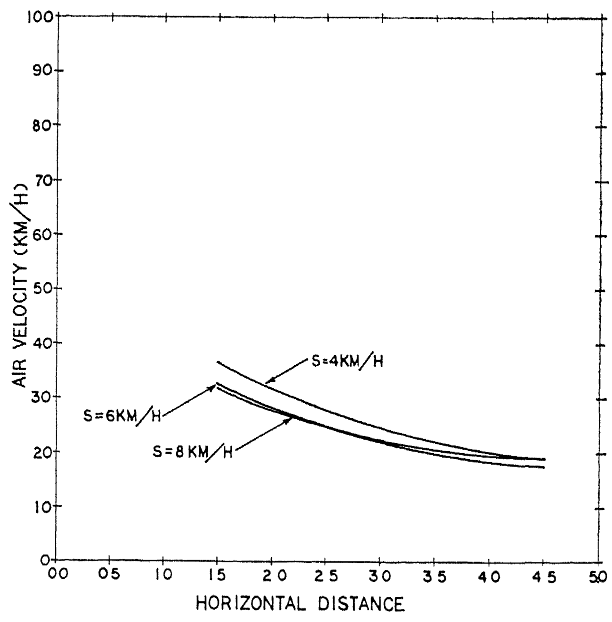

FIG. 6.—Effect of travel speed and horizontal distance from air outlet on air velocity delivered at 3.35 m height by LAFR sprayer.

MAFR(830S) with 7.0 cm (2.75 in) outlet opening, and LAFR(3P50) sprayers traveling at 6 km/h. The curve for the MAFR sprayer with 9.5 cm outlet opening would be between the curves for the HAFR and MAFR sprayer with 7.0 cm outlet opening and approximately parallel to the latter curve.

The effect of height above ground on air velocity delivered by the sprayers when traveling at 6 km/h and with 3.1 m horizontal distance between the air outlets and anemometer sensors is shown in Fig. 8. The curve for the MAFR sprayer with 9.5 cm outlet opening is slightly higher and approximately parallel to the curve for the MAFR(803S) sprayer with 7.0 cm (2.75 in) outlet opening. From the figure there appears to be little difference among air velocities delivered by the sprayers at higher elevation. All were low and apparently influenced by even light atmospheric wind. Generally, wind velocity increases at higher levels. Since wind direction changed frequently, sometimes assisting and at other times resisting the sprayer jets, the jets cannot be reliably compared when at the upper levels.

Table 1 lists air velocities derived from the regression equations for all sprayers used in the experiment. Velocities were determined for travel speeds, heights, and horizontal distances typical of the extremes and center of the experimental conditions. For all sprayers the highest air velocity occurred with the slowest travel speed, lowest height, and nearest horizontal distance. At the lowest height (1.22 m) and nearest horizontal distance (1.5 m), the HAFR and MAFR sprayer with outlet openings of 7.0 and 9.5 cm delivered about the same air velocities at each travel speed. The LAFR sprayer delivered considerably lower velocities at this position. At a height of 3.35 m and horizontal distances of 1.5, 3.1, and 4.6 m, the HAFR sprayer delivered the highest air velocity at each of the three travel speeds. The velocities delivered by the HAFR and MAFR sprayers with both outlet widths were considerably lower at the 5.49 m height than at the 1.22 m height. For example, at a travel speed of 6 km/h and horizontal distance of 3.1 m, the velocities delivered at 5.49 m were only 12, 17, and 14% of the velocities at 1.22 m for the HAFR, MAFR(9.5), and MAFR(7.0) sprayers, respectively.

The velocity delivered by the LAFR sprayer decreased very rapidly as distance from the outlet increased. At the 1.22 m height, 1.5 m horizontal distance, and 4 km/h travel speed, the air velocity was only 14% of the exit velocity. Randall (5) also showed that air velocities delivered by a sprayer with high exit velocity (324 km/h), but low airflow rate (1.53 m^3/s), decreased at a much faster rate than for sprayers delivering higher airflow rates. The same sprayer also delivered considerably lower air velocity when the travel speed increased. For example, at 2.9 m horizontal distance and 1.2 m height, the sprayer delivered air velocities of 44.0 and 22.9 km/h at travel speeds of 3.2 and 6.4 km/h, respectively.

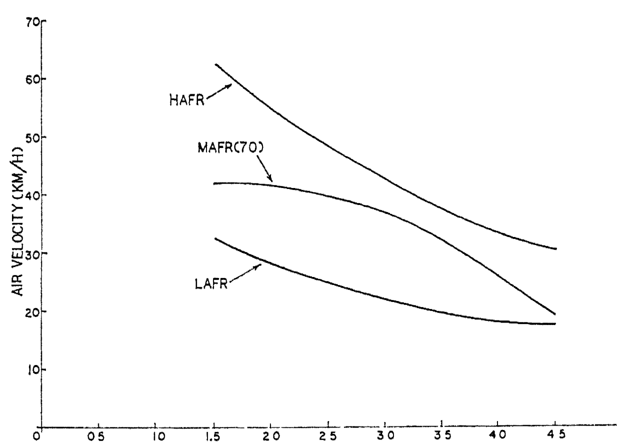

FIG. 7.—Effect of horizontal distance from air outlet on air velocity delivered at 3.35 m height by sprayers traveling at 6 km/h.

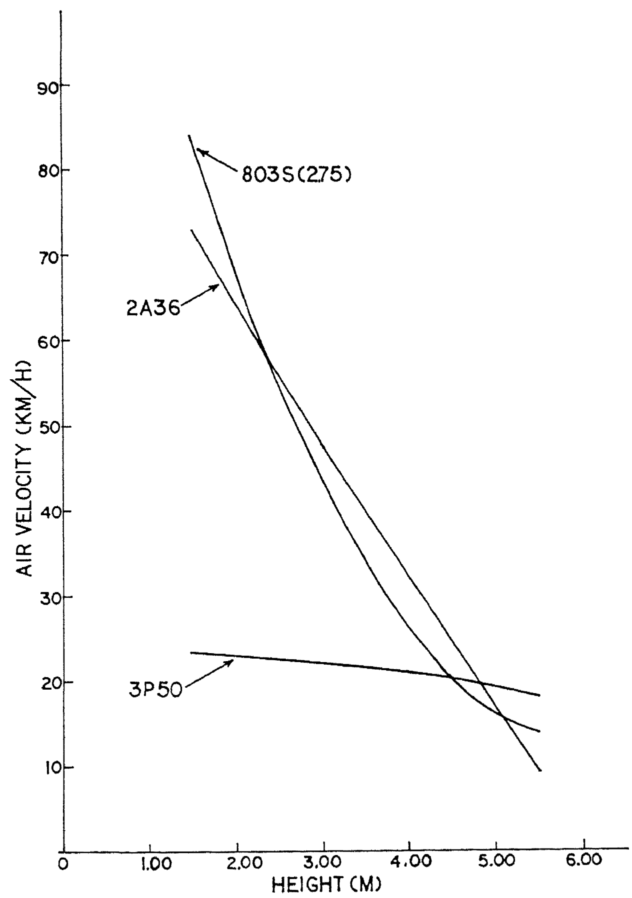

FIG. 8.—Effect of height above ground on air velocity delivered by sprayers traveling at 6 km/h and 3.1 m (horizontal distance) away.

ORCHARD MEASUREMENTS

The multiple regression analyses showed significant influence from vertical distance and travel speed. However, most of the correlations were lower than for the multiple regression analyses of open field data. The lower correlations probably occurred because there was no attempt to identify variables which account for the effect of tree structure on the sprayer jets.

The regression equations were used to calculate the sprayer air velocities at two heights and three travel speeds as listed in Table 2. At each of the three travel speeds, the HAFR sprayer delivered higher air velocities at the 1.22 m height than the other sprayers. The same is true for the air velocities delivered at the 3.35 m height in the center of the tree. The air velocities delivered by the sprayers at the 3.35 m height on the far side of the tree were quite scattered. In all cases, air velocities at the 1.22 m height were considerably higher than at the 3.35 m height. Also, each sprayer delivered lower air velocities at the 1.22 m height as travel speed increased.

Table 3 shows a comparison of velocities delivered in an open field, in the center of a tree, and on the far side of a tree. The velocities were computed from the regression equations. Generally, but not

TABLE 1.—Resultant Velocities Derived from Multiple Regression Equations.

Sprayer	Horizontal Distance (m)	Speed (km/h)	Velocity (km/h) Height (m) 1.22	3.35	5.49
HAFR	1.5	4.0	111.0	65.7	23.9
		6.0	107.0	62.1	20.4
		8.0	104.0	58.5	16.8
	3.1	4.0	81.1	45.2	16.7
		6.0	77.6	41.7	9.13
		8.0	74.0	38.1	5.56
	4.6	4.0	60.1	33.5	10.1
		6.0	56.6	29.9	6.52
		8.0	53.1	26.3	2.96
MAFR(9.5)	1.5	4.0	113.0	47.8	20 4
		6.0	110.0	44.6	17.2
		8.0	104.0	38.1	10.8
	3.1	4.0	104.0	43.0	20.7
		6.0	101.0	39.8	17.5
		8.0	94.0	33.4	11.0
	4.6	4.0	80.2	24.6	7.29
		6.0	77.1	21.4	4.11
		8.0	70.7	15.0	— 2.30
MAFR(7.0)	1.5	4.0	112.0	44.1	9.69
		6.0	107.0	41.7	10.1
		8.0	101.0	39.3	10.6
	3.1	4.0	104.0	41.8	13.0
		6.0	92.8	36.4	13.2
		8.0	81.7	31.0	13.5
	4.6	4.0	82.3	25.9	2.76
		6.0	65.4	17.5	2.87
		8.0	48.6	9.13	1.98
LAFR	1.5	4.0	45.4	35.0	23.0
		6.0	40.8	31.3	20.0
		8.0	39.2	30.4	20.0
	3.1	4.0	27.3	23.2	17.4
		6.0	23.2	20.7	16.6
		8.0	21.9	21.1	18.6
	4.6	4.0	15.5	17.7	18.2
		6.0	11.9	16.5	19.4
		8.0	11.1	18.2	23.4

always, the velocities were higher for positions in the open than for corresponding positions in the center or far side of a tree. In some areas, it appears that changes in wind direction or velocity may have influenced the air velocities. Tree structure may have caused the air velocities to increase in some cases.

Although the peach trees used in this study were well pruned and beginning to lose some leaves, they exerted considerable influence on the sprayer air velocities. Many more orchard experiments will be needed to explain the effect of tree structure on sprayer air jets.

TABLE 2.—Resultant Velocities Derived from Multiple Regression Equations for Orchard Data.

Sprayer	Horizontal Distance (m)	Travel Speed (km/h)	Velocity (km/h) Height (m) 1.22	3.35
		Center of Tree		
HAFR	3.1	4.0	109.0	37.2
		6.0	93.2	39.1
		8.0	74.5	37.8
MAFR(7.0)	3.1	4.0	89.9	25.4
		6.0	87.4	30.1
		8.0	69.4	19.1
MAFR(9.5)	3.1	4.0	65.9	29.5
		6.0	63.6	30.7
		8.0	40.6	11.3
		Far Side of Tree		
HAFR	4.6	4.0	83.3	28.5
		6.0	74.2	25.3
		8.0	62.6	19.6
MAFR(9.5)	4.6	4.0	57.4	34.4
		6.0	50.8	23.6
		8.0	52.0	20.6
MAFR(7.0)	4.6	4.0	69.7	26.2
		6.0	65.7	29.5
		8.0	48.4	19.5

TABLE 3.—Comparison of Resultant Velocities Delivered by Sprayers Traveling 6.0 km/h in the Orchard and in the Open.

Sprayer	Location	Horizontal Distance (m)	Velocity (km/h) Height (m) 1.22	3.35
HAFR	Open	3.1	107.0	62.1
	Center of tree	3.1	93.2	39.1
	Open	4.6	56.6	29.9
	Far side of tree	4.6	74.2	25.3
MAFR(9.5)	Open	3.1	101.0	39.8
	Center of tree	3.1	87.4	30.1
	Open	4.6	77.1	21.4
	Far side of tree	4.6	50.8	23.6
MAFR(7.0)	Open	3.1	92.8	36.4
	Center of tree	3.1	63.6	30.7
	Open	4.6	65.4	17.5
	Far side of tree	4.6	65.7	29.5

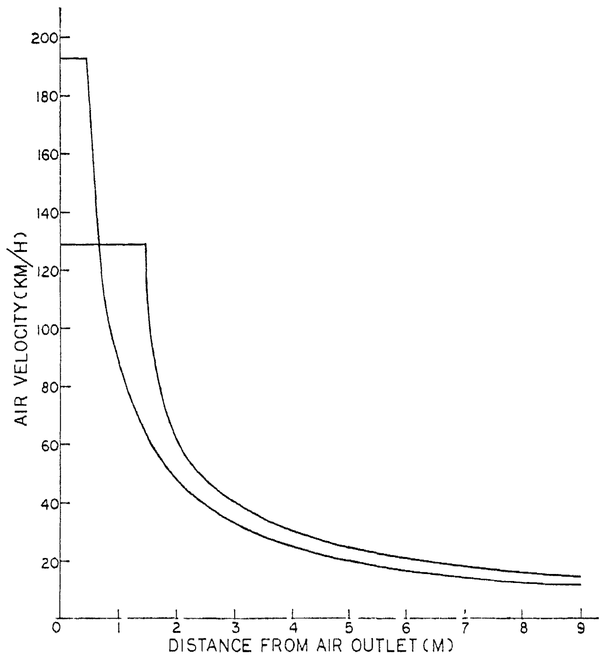

FIG. 9.—Comparison of air velocities delivered by two sprayers with the same air horsepower at outlet but different discharge velocity and airflow rates.

DISCUSSION OF AIR VELOCITIES DELIVERED BY AIR SPRAYERS

Figure 9 shows a comparison of the air velocities calculated as shown by Reichard *et al.* (7) for two sprayers with the same air horsepower at the outlet but with different discharge velocities and mass flow rates. One sprayer delivers 33.0 m^3/s at 129 km/h, and the other delivers 14.7 m^3/s at 50% higher velocity (193 km/h). Figure 9 shows that the sprayer delivering the higher air velocity, but the lower airflow rate, produced a higher velocity for only a very short distance. At 3.1 m from the air outlet, the sprayer delivering the lower airflow rate at the outlet produced 21% higher air velocity. This example may be somewhat oversimplified because of slight differences in fan efficiencies for the two cases. However, it indicates that for a given power input it is better to use the lowest air velocity needed at the outlet with the highest airflow rate.

A certain minimum air velocity is needed to convey and effect impingement of spray drops. Reichard *et al.* (6) showed that several nozzles commonly used with orchard air sprayers produce a very wide range of droplet sizes. There are no definitive data known to show the velocity needed to make various sizes of droplets impinge on a compliant leaf in an airstream. Several researchers, including Miles *et al.* (4), have shown that larger spray droplets produce higher deposition efficiencies on rigid targets than do small droplets. Also, a certain velocity is needed to streamline the leaves and allow the spray to penetrate the edge of the tree canopy. Randall (5) stated that an air velocity of 44 km/h was needed for Cox apple trees because it would reduce the projected leaf area to about 40% of its original area. More research is needed to determine the air velocities needed to produce high deposition efficiencies under conditions encountered by growers who use air sprayers.

ACKNOWLEDGMENTS

The authors acknowledge the assistance of W. Alvey, P. Keck, and A. Swank, electronic technicians, and W. Boyes and D. Collins, mechanical technicians, in developing instrumentation, conducting the experiments, and analyzing the data. They also acknowledge the help of Ms. D. Baum, secretary, in data processing.

LITERATURE CITED

1. Fox, R. D., R. D. Brazee, W. R. Alvey, W. R. Boyes, and A. W. Swank. June 1977. A Data Management System for Atmospheric Flow in Plant Regions. ASAE Paper No. 77-4027, 1977 ASAE Annual Meeting, Raleigh, N. C.
2. Hall, F. R., H. Y. Forsythe, Jr., B. M. Jones, D. L. Reichard, and R. D. Fox. 1975. Comparison of Orchard Sprayers for Insect and Disease Control on Apples, 1966-1969. Ohio Agri. Res. and Development Center, Res. Bull. 1078.
3. Hall, F. R., D. L. Reichard, and H. R. Krueger. 1975. Dislodgeable Azinphosmethyl Residues from Air Blast Spraying of Apple Foliage in Ohio. Archives of Environmental Contamination and Toxicology, 3:352-363.
4. Miles, G. E., D. E. Threadgill, J. F. Thompson, and R. E. Williamson. 1975. Simulation of Droplet Deposition on Bodies with Rectangular Boundaries. Transactions of ASAE, 18: 74-78.
5. Randall, J. M. 1971. The Relationships Between Air Volume and Pressure on Spray Distribution on Fruit Trees. J. Agri. Engr. Res., 16 (1):1-31.
6. Reichard, D. L., H. J. Retzer, L. A. Liljedahl, and F. R. Hall. 1977. Spray Droplet Size Distributions Delivered by Air Blast Sprayers. Transactions of ASAE, 20 (2):232-237, 242.
7. Reichard, D. L., R. D. Fox, R. D. Brazee, and F. R. Hall. June 1977. Air Velocities Delivered by Orchard Air Sprayers. ASAE Paper No. 77-1037, 1977 ASAE Annual Meeting, Raleigh, N. C.
8. Steiner, P. W. 1969. The Distribution of Spray Material Between Target and Non-target Areas of a Mature Apple Orchard by Airblast Equipment. M.S. Thesis, Cornell Univ.

Spray Droplet Sizes Delivered by Orchard Air Sprayers

D. L. REICHARD,[1] H. J. RETZER,[2] and F. R. HALL[3]

SUMMARY

Spray droplet sizes delivered by atomizers on orchard air sprayers were measured. All atomizers produced a very wide range of droplet sizes but some delivered a much greater proportion of large drops than others. Nearly all of the droplet distributions contained the largest proportion of droplets in either of the two smallest size classes (7.2 to 22.5 or 22.5 to 37.5 μm). The droplet size distributions also varied with the position measured in the spray pattern.

INTRODUCTION

The size of droplets delivered by an orchard air sprayer greatly influences pest control. If the droplets are too small, the deposition efficiency is decreased and drift is increased. If the droplets are too large, the sprayer air velocity may not be sufficient to carry the drops to the top of the trees, and coverage may be inadequate to control a pest. Present evidence as to which droplet sizes are best for use with orchard sprayers is not conclusive, partly due to lack of information on droplet sizes delivered by orchard air sprayers.

METHOD AND MATERIALS

A model OAP-200X optical array spectrometer probe (Fig. 1) and model PDS-100 particle data system (Particle Measuring Systems, Inc.[4]) were used

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[4]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U. S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

FIG. 1.—Optical array spectrometer probe used to measure droplets delivered by 2A36 sprayer.

to measure the droplet size distributions in water sprays delivered by orchard air sprayers. The system measured and counted spray droplets in each of 22 size classes ranging from 7.5 to 337.5 micrometers (μm). Several different statistics were calculated for the droplet size distributions, but just the volume median diameter (VMD) is discussed in this paper. Half of the total spray volume is included in drops larger than the VMD.

Spray droplets delivered by three different sets of disc-core type nozzles on a model 2A36 sprayer (F. E. Myers and Bros. Co.) were measured in the center of the spray pattern and 46 cm from the nozzles. All nozzles were operated at 14.1 kg/cm^2 pressure and had flow rates as recommended by a representative of the sprayer manufacturer for each of the 10 nozzle positions. The nozzle positions were numbered from bottom to top of the outlet.

Two of the nozzle sets were manufactured by Spraying Systems Co. and the other set was manufactured by Delavan Manufacturing Co. The Delavan Raindrop nozzles were designed to produce larger drops than other disc-core type nozzles with the same capacity. In this paper, the Spraying Systems and Delavan nozzles are designated as SS and Del, respectively. The Del set of nozzles delivered 0.65 l/s and the SS sets delivered 0.63 and 0.21 l/s, respectively. To determine if the sprayer air blast reduced the sizes of spray droplets, droplet size distributions produced by an SS2-23 nozzle in a chamber containing still air were measured.

Spray droplet sizes were also measured at 46 cm from the atomizers on a model 3P-50 Kinkelder sprayer. The 3P-50 sprayer relies primarily on its high velocity (about 89 m/s) air stream to break up the liquid delivered at low pressures through a triangular-shaped device. The valve was set so each atomizer would deliver 6.3 ml/s during the experiment.

Spray droplet sizes were measured at several places in the spray patterns delivered by SS10-25 (No. 10 disc and No. 25 core) and Del 5-25 (Raindrop series) nozzles mounted on the horizontal centerline of the 2A36 sprayer. Measurements were made on the vertical centerlines of the nozzles, both above and below the horizontal centerlines of the nozzles.

RESULTS AND DISCUSSION

It is known that a spray droplet will shatter if the relative velocity between the droplet and air stream becomes too great. Spray droplet sizes delivered by a SS2-23 nozzle at position No. 4 on the 2A36 sprayer were compared with the droplets delivered by the same nozzle in calm air. Fig. 2 shows that the SS2-23 nozzle delivered a greater proportion

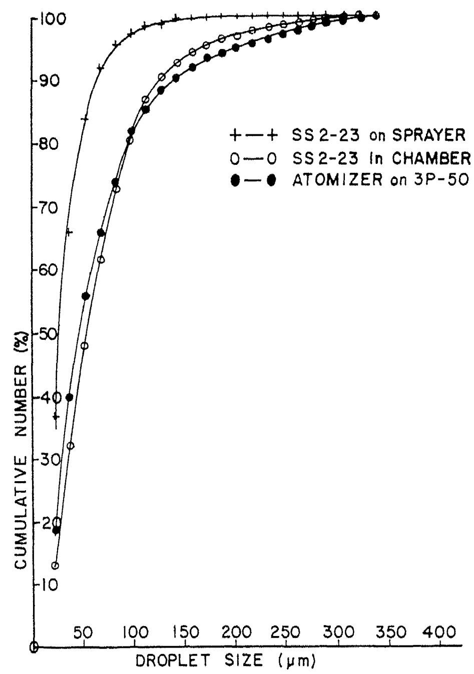

FIG. 2.—Droplet size distribution for the following: SS2-23 in chamber and at position No. 4 on 2A36 sprayer; atomizer at position No. 4 on 3P-50 sprayer.

of smaller droplets in air blast than in the chamber. The VMD for the spray in the air blast and calm air was 102 and 187 μm, respectively.

Table 1 shows the flow rates and VMD of the sprays delivered by different nozzles in the high-flow-rate set of SS nozzles. Some of the positions are not shown because they had the same nozzle as one of the other positions shown in the table. There was some difference in the VMD delivered by the same nozzles at different positions, probably caused mainly by the variation in air velocity around the outlet of the sprayer. Table 1 shows a trend toward higher VMD values as the flow rate capacities of the nozzle increased. Both the low-rate set of SS nozzles and the Del nozzles also tended to deliver higher VMD values as their flow rate capacities increased. The mean VMD was highest (213 μm) for the Del nozzle set,

TABLE 1.—VMD Delivered at 46 cm from SS High-rate Nozzles Set on 2A36 Sprayer.

Position No.	Nozzle (disc-core)	Flow Rate (ml/sec)	VMD (μm)
2	SS3-25	25	125
3	SS4-25	39	143
5	SS5-25	47	194
6	SS7-25	74	222
7	SS8-25	86	233
8	SS10-25	108	243

next highest (187 μm) for the SS high-rate nozzle set, and lowest (148 μm) for the SS low-rate nozzle set.

When compared with a SS nozzle delivering about the same flow rate, the atomizers on the 3P-50 delivered a much coarser spray. The SS1-13 nozzle at position No. 1 on the 2A36 sprayer delivered a spray with VMD = 108 μm, and the mean VMD produced by the four atomizers on the 3P-50 sprayer was 214 μm. Fig. 2 shows the cumulative number percentages of various sizes of droplets in a spray delivered by an atomizer on the 3P-50.

All of the sprays delivered at 46 cm from the atomizers on the 2A36 and 3P-50 sprayers contained a very wide range of droplet sizes. Nearly all sprays contained the largest proportion of droplets in either of the two smallest size classes (7.5 to 22.5 and 22.5 to 37.5 μm). Nearly all sprays also contained 10% or more droplets in the smallest size class. However, even the distributions in which 30-40% of the droplets were in the smallest size class contained less than 1% of the spray volume in the smallest size class. Some of the atomizers delivered no droplets in the largest size class (322.5 to 337.5 μm), but most of them contained some droplets (less than 1%) in that class. More details on droplet sizes delivered by various nozzles and sprayers are included in publications by Reichard *et al.* (1, 2).

Droplet size measurements at several positions in the spray patterns of SS10-25 and Del 5-25 nozzles indicated that VMD varied with position in the pattern. Measurements at 0.91 m (horizontal distance) from the Del 5-25 nozzles and at 15.2 cm increments on the vertical centerline of the nozzle showed the lowest VMD (188 μm) at 15.2 cm above the nozzle. The VMD values gradually increased to 249 μm and 270 μm at 45.7 cm above and below the position with the lowest VMD respectively. Measurements at 3.66 m from the SS10-25 nozzle and at 61.0 cm increments on the vertical centerline of the nozzle showed considerably less variation in VMD with position in the spray pattern than for sprays delivered at 0.91 m by the same nozzle and the Del 5-25 nozzle. At 3.66 m and at the same height as the nozzle, the SS10-25 nozzle delivered a spray with a VMD of 168 μm. At 61.0 and 122.0 cm above the nozzle, the VMD's were 169 and 170 μm, respectively. At 182.9 cm above and 61.0 cm below the nozzle, the VMD's were 188 and 195 μm, respectively. Due to the direction of fan rotation, the 2A36 sprayer air jet tended to push the spray upward on the side of the sprayer where the droplets were measured. Probably the turbulence of the sprayer air jet tended to make the droplet size distributions over the spray pattern more uniform as distance from the nozzle increased.

All droplet size distributions delivered by the atomizers in these experiments contained a very wide range of droplet sizes. More experiments are needed to determine the best range of droplet sizes for controlling orchard pests, but it would seem desirable to have atomizers which deliver fewer very small droplets than delivered by the nozzles used in these experiments.

LITERATURE CITED

1. Reichard, D. L., H. J. Retzer, L. A. Liljedahl, and F. R. Hall. 1977. Spray Droplet Size Distributions Delivered by Air Blast Orchard Sprayers. Transactions of ASAE, 20:232-237, 242.
2. Reichard, D. L., F. R. Hall, and H. J. Retzer. 1978. Distributions of Droplet Sizes Delivered by Orchard Air Sprayers. J. Econ. Entomol., 71:53-77.

The Effects of European Red Mite Feeding on the Growth and Yield of Spur-Type Delicious Apple[1]

W. G. KLOPFENSTEIN[2] and R. P. HOLDSWORTH[3]

INTRODUCTION

The apple cultivar, Red Delicious, is a low producing variety (1), at least in the Midwest and Northeast. It is also susceptible to outbreaks of the European red mite, *Panonychus ulmi* (Koch). In spite of its drawbacks, Red Delicious comprises about 33% of Ohio's apple trees, with spur-types being widely planted. It is suspected that mite feeding could be a factor contributing to low productivity.

Previous research has shown Red Delicious productivity to be affected by the European red mite (2, 3). In a 2-year study in New York, European red mites were allowed to build up to nearly 300 per leaf in standard Red Delicious and Cortland trees, while mites were suppressed in corresponding control trees. At the end of the first season, the trees with few mites had greater trunk growth. During the second year, mites were controlled on all trees, but there was a carryover effect on the trees that had heavy mite infestations the previous year. Bloom was 75% lighter on Cortland and 34% lighter on Red Delicious. Yields were reduced by 65% and 36%, respectively.

Since fruit bud formation occurs during the early summer of the year before bloom, it appears that the reductions in bloom and yield were caused by mites feeding in the year before harvest. It should be pointed out, however, that the mite populations in this experiment would cause discoloration of leaves and therefore were much higher than commercial growers would tolerate.

Hall and Ferree (4) in Ohio have shown that low mite densities can affect the photosynthesis of Red Delicious. They added 15 two-spotted spider mites (*Tetranychus urticae* (Koch)) per leaf to young trees. There was a reduction in photosynthesis as early as 7 days after the mites were placed on the leaves. The significance of this study is that photosynthesis was reduced before the eye could detect damage (yellowing) to the leaves.

The authors thought it would be of value to determine the effect of low to moderate populations of European red mite on the growth and yield of spur-type Red Delicious in the early production years.

[1]The authors thank Dr. David C. Ferree, Dept. of Horticulture, and David J. Horn, Dept. of Entomology, for advice and consultation.

[2]Instructor, Dept. of Biology, Sinclair Community College, Dayton, Ohio. This study was performed by the senior author as a partial fulfillment of the Ph.D. requirements at The Ohio State University.

[3]Professor, Dept. of Entomology, The Ohio State University and Ohio Agricultural Research and Development Center.

MATERIALS AND METHODS

This study was conducted in 1974, 1975, and 1976 at The Ohio State University Overlook Farm in Fairfield County. 'Miller Sturdeespur' Red Delicious trees on MM 106 rootstock were used. The trees were 2 years old when planted in 1971, and were just coming into bearing in their fourth year in the field (1974).

During the 3 years of the study, all maintenance sprays followed a Captan-Imidan integrated control schedule (5). (Dormant oil was omitted in 1975.) Spray concentration was 3X, applied by air blast sprayer.

Twenty-eight trees were divided into four treatments. The experimental design was one of seven randomized complete blocks, with a single tree of each treatment present in each block. The European red mites in treatment 1 were kept low by spraying as required with Carzol 92SP, at either 2 or 4 oz per acre. The European red mites in treatments 2 and 3 were allowed to build up. The intent was to hold treatment 2 to about 20 mites per leaf, but allow the mites on treatment 3 to increase to 30 per leaf or more. Since there were high populations of predaceous mites, *Amblysieus fallacis* (Garman) and *Zetzellia mali* (Ewing), it was necessary to destroy predaceous mites by spraying with Sevin 50 W, 5 lb per acre, in order to obtain the desired density of red mites in treatments 2 and 3. Treatment 4 served as a control for any adverse effect of miticide on growth and yield, *i.e.,* any time a miticide was sprayed on treatments 1 or 2 or 3, it also was sprayed on 4.

In 1976 mites were suppressed on all trees by using Omite 30 W, 2 lb per acre, on July 6 and 19, August 5 and 19.

European red mite populations were estimated by the random collection of leaves from the lower two-thirds of the crown. Sample sizes were 15 leaves per tree in 1974 and 25 leaves per tree in 1975 and 1976. Mites were brushed on to glass plates and counted under a microscope.

Tree growth was measured by recording seasonal changes in trunk circumference and shoot extension. The vegetative condition of the leaves was measured by an analysis of foliar nitrogen (percent dry weight, Kjeldahl method). Fruit production was recorded in 1975 and 1976 as fruit number and total weight per tree. (In 1974, the few apples produced were removed during the summer and not recorded.)

TABLE 1.—Differences in Average European Red Mite Populations, According to Treatment, 1974.

	Intended Density			
Date	1. Low	2. Intermediate†	3. High†	4. Miticide Control†
August 23	9.6 a*	9.1 a	8.0 a	0.7 b
September 4	12.6 a	17.9 a	24.7 a	1.3 b
September 16	12.9 b	51.1 a	51.7 a	7.0 b

*Means on the same date followed by the same letter do not differ at 5% level.
†Sprayed with Sevin 50 W, 5 lb per acre, on July 11 and 22. Treatment 4 was sprayed with Carzol 92SP, 2 oz per acre, on June 25 and August 2.

TABLE 2.—Differences in Average European Red Mite Populations According to Treatment, 1975.

	Intended Density*			
Date	1. Low	2. Intermediate	3. High	4. Miticide Control
May 24	0.9 b†	2.6 a	2.4 a	0.9 bc
June 6	3.7 c	14.7 a	17.0 a	7.0 b
June 12	0.0 c	9.9 a	7.7 a	0.9 b
June 19	0.0 c	7.7 a	7.4 a	1.4 b
June 26	0.3 b	9.0 a	7.6 a	0.2 b
July 2	1.0 b	8.0 a	7.0 a	0.8 b
July 10	1.0 c	6.4 b	19.5 a	0.9 c
July 17	0.1 c	0.7 b	17.6 a	1.1 bc
July 28	0.3 bc	0.2 b	13.6 a	0.6 b
August 5	1.3 bc	0.7 c	22.5 a	3.4 b
August 13	0.7 b	0.6 b	18.7 a	1.1 b
August 20	0.1 b	0.0 b	4.7 a	1.0 b
August 27	1.8 b	0.5 b	6.6 a	0.7 b
September 9	1.2 b	0.2 c	3.3 a	0.9 bc

*European red mites were regulated by the following sprays: Carzol 92SP, 2 oz per acre, treatments 1 and 4, May 28; Carzol 92SP, 4 oz per acre, treatments 1 and 4, June 9; treatment 4, June 23; treatment 2, July 2 and 10; and treatments 2 and 4 on Sept. 9. Predaceous mites were destroyed by the use of Sevin 50 W, 5 lb per acre, on groups 3 and 4, July 15.
†Means on the same date followed by the same letter do not differ at the 5% level.

TABLE 3.—Average Number and Total Weight of Fruit Produced per Tree.

	1975		1976*	
Treatment Group	Number	Weight (lb)	Number	Weight (lb)
1	40.4 a†	13.4 ab	36.0 a	16.3 a
2	20.3 b	7.0 c	18.3 a	8.1 ab
3	22.9 b	8.1 bc	9.4 b	4.0 b
4	43.4 a	14.5 a	34.3 a	14.5 a

*Bud kill, due to frost, also contributed to overall low yield in 1976.
†Means in the same column followed by the same letter do not differ at the 5% level.

TABLE 4.—Average Foliar Nitrogen Content* (Percent Dry Wt.) in Each of the Four Treatment Groups as Sampled in 1974, 1975, and 1976.

	Date Sampled			
Treatment Group	August 15, 1974	July 6, 1975	September 3, 1975	August 11, 1976
1	2.47 a†	2.18 a	2.02 a	2.40 a
2	2.41 a	1.87 b	1.85 b	2.47 a
3	2.43 a	1.92 b	1.71 c	2.33 a
4	2.42 a	1.99 ab	2.01 a	2.41 a

*1.90% is the lower limit of nitrogen content to be considered acceptable.
†For each sample date, treatment groups followed by the same letter do not differ at the 5% level.

RESULTS

Mite populations were low at the beginning of the experiment. It was necessary to spray treatments 2 and 3 with Sevin (July 11 and 22) in order to cause an increase of European red mites. Table 1 shows the differences that finally occurred late in the 1974 season. Peak populations were more than 50 per leaf on treatments 2 and 3. The overall seasonal averages were low for all treatments, being 5.2, 8.3, 8.9, and 0.9, respectively, for treatments 1, 2, 3, and 4.

Mite densities were maintained at different levels in 1975 (Table 2). Treatments 1 and 4 were kept at a season-long average of 2 per leaf or less. Mites reached highest levels in treatment 3, averaging 9.7 per leaf for the first 48 days, and then increasing to an average of 12.2 per leaf for the second half of the season. The peak population in treatment 3 was 22.5 per leaf, a moderate density when compared with populations in the New York experiment (2, 3).

In 1976, mite populations were suppressed in all treatments, and averaged less than 1 per leaf for the entire season.

Table 3 shows the effect that European red mite feeding had on the number and total weight of fruit per tree. There is an apparent correlation between the late season peak of mites in 1974 on treatments 2 and 3 and the lower numbers and total weight of fruit in the same treatments in 1975. Likewise, there is an apparent correlation between the moderate densities on treatment 3 in 1975, and the decreased numbers and total weight of fruit in 1976. There was no effect on the weight of *individual* fruits in either 1975 or 1976. (Data not included here.) The fact that there were *fewer* fruits can be interpreted as an adverse effect of mite feeding on the formation of fruit buds. Mite stress apparently prevented some fruit buds from completing development, with the loss in crop being realized in the following year. The fact that weights of individual fruits did not differ among treatments suggests that there was no significant effect of mite feeding on the same year's crop.

Table 4 indicates that mite feeding had an effect on foliar nitrogen content in 1975. At mid-season and at season's end, the trees with more mites had lower foliar nitrogen levels. In both treatment groups 2 and 3 on Sept. 3, the nitrogen content was reduced below the desired minimum level of 1.90% dry weight.

Measurements of vegetative growth, *i.e.*, trunk circumference and shoot extension, showed no differences according to mite densities.

The small amount of miticides used during the 3-year period had no detectable effect on growth or yields. (For effect on crop, compare group 1 with 4, Table 3.)

DISCUSSION

One recommended mite control procedure in Ohio is that growers use a miticide when more than a few trees in a block show visible feeding damage ("bronzing"). In most years the first visible damage occurs in June or July, and miticides are applied. Late season outbreaks, however, are apt to be ignored. Many growers in Ohio stop spraying in late July or early August. Between the last spray and harvest it is not uncommon for European red mites to increase to 30 per leaf or more. Some growers are willing to tolerate late mite outbreaks on the basis that they come too late to affect the current crop. This view fails to consider the possibility that a late outbreak may have an adverse effect on the next year's crop.

This study demonstrates that young spur-type Red Delicious trees have a low tolerance to damage by moderate levels of European red mite. Late season outbreaks of European red mite should be controlled, since they may be contributing to the low produtivity of spur-type Red Delicious in their early bearing years.

LITERATURE CITED

1. Anonymous. Feb. 1978. Delicious Problem Is Growing. Amer. Fruit Grower, p. 15.
2. Chapman, P. J., S. E. Lienk, and O. F. Curtis. 1952. Responses of Apple Trees to Mite Infestations, I. J. Econ Entomol., 45:815-821.
3. Lienk, S. E., P. J. Chapman, and O. F. Curtis. 1956. Responses of Apple Trees to Mite Infestations, II. J. Econ. Entomol., 49:350-353.
4. Hall, F. R. and D. C. Ferree. 1975. Influence of Two-Spotted Spider Mite on Photosynthesis of Apple Leaves. J. Econ. Entomol., 68:517-520.
5. Holdsworth, R. P. 1975. Integrated Control of Insects and Mites on Apple. *In* Commercial Fruit Spray Recommendations for Ohio. The Ohio State Univ., Coop. Ext. Serv., Bull. 506, pp. 22-28.

Insecticide Tests Against Rose Chafer Adults in Northern Ohio

ROGER N. WILLIAMS[1]

The rose chafer, *Macrodactylus subspinosus* (Fabricius), is an endemic American insect which attacks roses, grapes and various other fruits, and vegetable crops. The common name is derived from its attraction to rose flowers; however, the affinity to grape blossoms is even stronger. In most textbooks it is covered under grape pests since it is considered most injurious to this crop (4, 6, and 7). Its distribution ranges over southeastern Canada and the eastern half of the United States (5).

The larvae feed on the roots of grasses, grain, weeds, and other plants (1, 3, and 4) but are not considered to be of economic importance. Webster (9) reported finding 100 or more rose chafer grubs per square yard in sandy areas near Bellevue, Ohio. He also noted that the insect passed nearly a whole year in the ground, eggs being deposited in June and the adults emerging from the ground the following June.

The chafer adult usually makes its appearance in the vineyard suddenly and often in countless swarms. It feeds at first on the blossom buds (Fig. 1) or blossoms and later attacks the newly set fruit and the foliage (7). The destruction of the blossoms causes thin, scraggly clusters that are often not worth harvesting (8). Adults can be found in the vineyard for 3 or 4 weeks after emergence. Injury to Concord foliage is rarely severe enough to cause serious damage, although the leaves are often riddled by the beetles and have a tattered and ragged appearance. Thin-leaved varieties, such as Delaware, may have their leaves completely consumed except for the main veins.

METHODS AND MATERIALS

Two types of tests were conducted in the evaluation of insecticides for the control of the adult rose chafer.

Contact Toxicity Studies

These tests consisted of an evaluation of seven insecticides in a Potter spray tower in the Insecticide Test Laboratory at OARDC in 1976. Adults of the rose chafer were collected from a sandy Concord vineyard near North Kingsville just prior to bloom. Insects were collected from this particular area because it was suggested that the standard control, Methoxychlor, was not yielding satisfactory results.

Rose chafer adults were held for 24 hours at 24° ± 1.5° C and 60% RH prior to being treated. Stock solutions (1%) of all materials tested were prepared from technical grade materials using a mixture of acetone and olive oil, 19:1 (vol/vol), as the solvent.

Two replicates of 10 beetles each, selected at random, were anesthetized with ether and placed on filter paper in 9-cm glass petri dishes. Each replicate was sprayed with 5 ml of the insecticides at one of the concentrations. Checks consisted of two sets of 10 beetles each sprayed with the solvent. Treated beetles were removed from petri dishes and placed in paper cups with a moist wick of 5% honey-water and covered with a glass petri dish and held at 24° ± 1.5° C and 60% RH. Treatments were made on June 17, 1976, and mortality readings were made 24 hours later.

Field Screening Studies

This series of tests was conducted in a sandy vineyard at North Kingsville in 1977. Four of the compounds from the laboratory study were tested along with a synthetic pyrethroid, Pydrin, and four other insecticides. This experiment was conducted in a portion of a producing vineyard which had an annual problem with rose chafer adults.

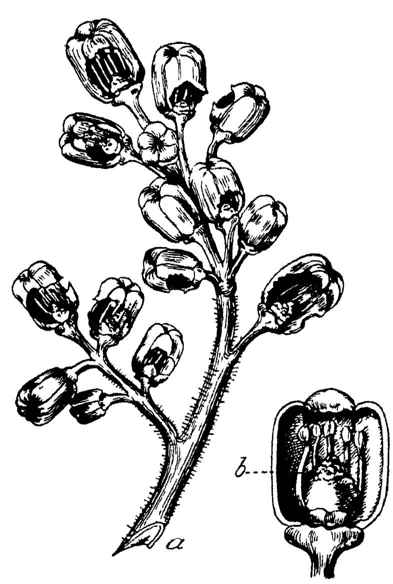

FIG. 1.—Damage caused by feeding of rose chafer: a. injury to grape blossom buds; b. injury to ovary resulting in destruction of the berry. After Johnson (2).

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TABLE 1.—Percent Mortality of Adult Rose Chafers 24 Hours After Treatment in Potter Spray Tower at Wooster, 1976.* †

Treatment	Percent Concentration			
	0.001	0.01	0.1	1.0
Methoxychlor	0	0	10	100
Thiodan	0	5	90	100
Diazinon	0	0	100	100
Guthion	0	35	100	100
Imidan	0	5	100	100
Sevin	0	0	60	100
Ambush	5	5	100	100

*Based on two replicates of 10 beetles each.
†Percent mortality in the treated controls was 0.

The Concord grape rows were planted on 10 ft centers with 8 ft between trunks in the row. Each row represented a block containing one replicate of each treatment. A replicate was composed of five adjacent vines in the row with four replicates/treatment. The 10 treatments were completely randomized within each block. A single application was made on June 5, soon after rose chafer adults were first observed feeding on the grape blossom buds. Application was made at the rate of ca. 100 gpa with a Hudson 6209, 2 gal Favorite sprayer at 40 psi.

Damage was evaluated by examining three different shoots on the three center vines in each plot. At each location, two clusters on a single shoot were rated according to the number of buds, flowers, or berries missing from the two clusters collectively. Ratings were as follows: 1 = 1-10 missing, 2 = 11-25 missing, and 3 = 26-40 missing. The damage ratings are means of the 12 readings made from a treatment on the given date.

TABLE 2.—Control of Rose Chafer Adults on Young Grape Clusters, North Kingsville, Ohio, 1977.

Treatment and lb ai/Acre	Mean Rating Grapes Removed/Two Clusters June 28
Penncap-M 2E 1	1.19 c*
Imidan 50WP 1.25	1.81 b
Alfa-tox 20% Methoxychlor 1.25 10% Diazinon 0.625	1.14 c
Guthion 50WP 0.5	1.36 bc
Pydrin 2.4E 0.2	1.25 c
Methoxychlor 50WP 1.6	1.28 c
Sumithion 8EC 1.5	1.39 bc
Diazinon 50WP 1	1.81 b
Zolone 3EC 2.25	1.58 bc
Untreated Check	2.36 a

*Means not followed by same letter are significantly different at the 5% level of probability using DMRT.

RESULTS AND DISCUSSION

Contact toxicity studies in the laboratory seemed to verify growers' suspicions that Methoxychlor was not killing the chafer adults (Table 1). In fact, all of the other compounds y'elded higher mortalities. At the 0.1% level, only three compounds (Methoxychlor, Thiodan, and Sevin) did not kill all of the beetles. Guthion was the most effective insecticide in the laboratory tests.

It is interesting to note that when a preliminary observation was made 45 minutes after treatment in all rates of the Ambush treatments, every insect was down and apparently dead. However, at the time of the 24-hour reading in the lower rates, many had recovered. Ambush is a synthetic pyrethroid and typical of pyrethrins, it gave a quick knockdown, but the lower rates failed to kill the beetles.

All of the compounds in Table 1 are labeled for use on grapes with the exception of Ambush. However, they are not all labeled for use against the rose chafer on grapes.

Field screening plots did not seem to substantiate the results in the laboratory studies. Actually Methoxychlor was not significantly different from the lowest rating (least damage) which was achieved in the Alfa-tox plots. Methoxychlor was slightly better than Guthion in field ratings (Table 2). It was anticipated that Guthion would do better in the field than it did. However, it must be kept in mind that these are different classes of insecticides with great differences in the length of activity in the residues. Organophosphate insecticides such as Guthion are generally less residual than chlorinated hydrocarbon compounds such as Methoxychlor. This may account for part of the differences between laboratory and field studies.

Diazinon and Methoxychlor were included in both the laboratory and the field tests. Alfa-tox was only employed in the field evaluation. It is a mixture of Diazinon and Methoxychlor and at the rates used proved to be the most effective compound yielding the lowest index rating. It must be remembered that more total insecticide was applied with Alfa-tox than either of the two constituents alone.

Field screening was more difficult to evaluate than the contact toxicity studies because populations were very low and because it is difficult to know how many beetles were killed by a specific pesticide under field conditions. Due to the relatively low chafer population in 1977, it was not meaningful to make counts of the number of chafers per cluster on the various treatments.

SUMMARY AND CONCLUSIONS

Damage to grapes by the rose chafer, *Macrodactylus subspinosus* (Fabricius), is a common occurrence in sandy soils in the grape-producing regions of the eastern United States (2). Numerous insecticidal compounds have been tried over the years, but none have been completely successful when the chafers are present on the vines in large numbers. This may be due to several factors over which the grower has little control, but it would seem logical that the primary factor would be that as beetles invade the vines each can do some damage before it is killed. Thus, to have complete control it would be necessary to completely exclude the pest from the vineyard.

It was concluded from this research that Methoxychlor is still an effective pesticide against the rose chafer, even in areas where it has been employed in spray schedules for many years. Based on these results, Alfa-tox will be added to the control recommendations for the rose chafer. Although several other materials gave good results, they are not labeled for the rose chafer.

LITERATURE CITED

1. Chittenden, F. H. and A. L. Quaintance. 1916. The Rose-Chafer: A Destructive Garden and Vineyard Pest. USDA, Farmers' Bull. 721, 8 pp.
2. Johnson, F. 1911. Vineyard Spraying Experiments Against the Rose-Chafer in the Lake Erie Valley. USDA, Bur. Entomol. Bull. 97, pt. 3, pp. 53-64.
3. Jubb, G. L., Jr. 1975. Vineyard Insect Pests —The Rose Chafer. Eastern Grape Grower, 1(4):10-11.
4. Metcalf, C. L., W. P. Flint, and R. L. Metcalf. 1962. Destructive and Useful Insects, Their Habits and Control. McGraw-Hill Book Co., N. Y., 1,087 pp.
5. Ritcher, P. O. 1966. White Grubs and Their Allies. Ore. State Univ. Press, Corvallis, 219 pp.
6. Saunders, W. 1883. Insects Injurious to Fruits. J. B. Lippincott & Co., London, 436 pp.
7. Slingerland, M. V. and C. R. Crosby. 1922. Manual of Fruit Insects. The Macmillan Co., N. Y., 503 pp.
8. Still, G. W. and R. W. Rings. 1973. Insect and Mite Pests of Grapes in Ohio. Ohio Agri. Res. and Dev. Center, Res. Bull. 1060, 30 pp.
9. Webster, F. M. 1894. The Rose Chafer or Rose Bug: How to Deal with It. 27th Ann. Rept., Ohio State Hort. Soc., (1893-1894), pp. 91-98.

Apple Powdery Mildew Eradication and Bloom Delay with Dormant Season Surfactant Sprays

ROBERT A. SPOTTS[1]

INTRODUCTION

Apple powdery mildew is an important disease in apple producing regions of the world (1). The disease is caused by the fungus *Podosphaera leucotricha* (Ell. & Ev.) Salm., which overwinters in vegetative and fruit buds (2) and infects young, emerging tissue. During the growing season, vast quantities of conidia are produced which infect young blossoms, leaves, and fruit under the proper environmental conditions.

Currently, several fungicides are used commercially to control powdery mildew. These fungicides are applied frequently throughout the growing season and may not give acceptable mildew control on susceptible cultivars when weather favors disease development. The cost of apple powdery mildew control is probably between 10% and 20% of the total disease control cost.

Although the antimicrobial properties of surfactants are well known, this experimental use for control of powdery mildew is a relatively recent development. Many surfactants, especially the anionic and cationic materials, are toxic to apple foliage (6). The cationic compound didecyldimethylammonium bromide (DDAB) effectively eradicated *P. leucotricha,* but caused an increase in fruit russet (9, 10). Similarly, the nonionic surfactant NC5630 (based on condensation products of cetyl and oleyl alcohol with ethylene oxide) was extremely active against *P. leucotricha* but caused fruit damage in field tests (4).

Fruit and foliar phytotoxicity problems were overcome when these chemicals were applied to trees during the dormant season (5). Excellent eradication of mildew from infected buds was obtained with autumn sprays of "Offshoot O" and "Offshoot T" (Atlas Chemical Industries, Inc.). Application of Offshoot O in March caused a 3-4 week delay in bud break, but thereafter growth quickly returned to normal. Additional work showed that the individual component esters of Offshoot O were powdery mildew eradicants, but their activities were inferior to that of the mixture (7). Because a considerable contribution to fungitoxicity by other formulants in the commercial mixture was apparent, the nonionic surfactants Tween 20 (Atlas Chemical Ind., Inc.) and Ethylan CP (Lankro Chemicals Ltd.) were studied. Ethylan CP controlled mildew as well as Offshoot O.

Recently it was shown that one application of a variety of surfactants, including Ethylan CP and Triton X45 (Rohm and Haas), to apple trees during the dormant season resulted in a significant reduction in primary mildew the following season (3, 8). An October application gave better control than one in March. Autumn treatments delayed bud burst and flowering up to 2 weeks whereas March treatments caused a 4-6 week delay. Triton X45 was the best mildew eradicant, but yield was reduced, perhaps because delayed flowering interfered with optimum pollination time.

MATERIALS AND METHODS

Several surfactants[2] were evaluated for control of apple powdery mildew in 1977 at OARDC (Table 1). The Triton nonionic surfactants are alkylaryl-

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[2]Triton surfactants and Dikar supplied by Rohm and Haas Co., Offshoot T by Procter and Gamble, and Nufilm 17 by Miles Chemical and Fertilizer Corp.

TABLE 1.—Effect of One Dormant Application of Several Surfactants on Powdery Mildew on Cortland Foliage.

	May 10		June 9	
Treatment*	1% a.i.†	5% a.i.	1% a.i.	5% a.i.
Triton X100	2.0‡	4.2	18	39
Triton N57	1.7	2.8	25	20
Triton X35	5.2	3.0	25	27
Triton CS7	1.9	1.3	26	25
Offshoot T	2.6	1.0	28	32
Nufilm 17	1.5	2.3	31	41
Dikar 76WP	0.6		22	
Water	3.0		24	
LSD(p = 0.05)	3.5		16.0	

*Dikar 76WP 2.0 lb/100 gal applied April 11, 21, 29; May 6. All other treatments applied March 9.
†a.i. = active ingredient calculated on w/v basis.
‡Values represent average percent mildewed leaves on 60 terminals per treatment.

TABLE 2.—Effect of One Dormant Application of Several Surfactants on Cortland Bud Development.

	Growth Stage*					
	April 11		April 20		April 29	
Treatment†	1% a.i.‡	5% a.i.	1% a.i.	5% a.i.	1% a.i.	5% a.i.
Triton X100	HIG	GT	P	P	PF	B
Triton N57	HIG	GT	B	OC	PF	B
Triton X35	HIG	HIG	B	B	PF	PF
Triton CS7	HIG	GT	P	OC	PF	B
Offshoot T	HIG	GT	P	OC	B	B
Nufilm 17	HIG	HIG	B	B	PF	PF
Dikar 76WP	HIG		B		PF	
Water	HIG		B		PF	

*GT = green tip; HIG = half-inch green; OC = open cluster; P = pink; B = bloom; PF = petal fall.
†Dikar 76WP 2 lb/100 gal applied April 11, 21, 29; May 6. All other treatments applied March 9.
‡a.i. = active ingredient calculated on a w/v basis.

oxypolyethoxyethanol compounds and vary in the number of ethylene oxide groups from 3 (Triton X35) to 10 (Triton X100). Triton CS7, however, is the sodium salt of an amphoteric surfactant and is anionic. Offshoot T is a 63% mixture of fatty alcohols, mainly C_8 and C_{10}, used for de-suckering tobacco. Nufilm 17 (poly-1-p Methen-8, 9-diyl) is a pesticide extender.

Each treatment was applied at 1% and 5% active ingredient (weight/volume basis) to six randomized scaffold limbs of mature Cortland on seedling rootstocks. Limbs were sprayed until runoff with a pressurized hand sprayer at 30 psi on March 9. Unsprayed trees were at half-inch green on April 11. Powdery mildew counts were made on all leaves of 10 terminals per limb on May 10 and June 9. Stages of bud development were determined for all limbs on April 11, 20, and 29.

RESULTS AND DISCUSSION

Due to reduction in overwintering inoculum resulting from low January temperatures, apple powdery mildew was not severe during the 1977 season. No significant mildew control was observed with any of the surfactants at the 1% or 5% rates (Table 1). No trend in disease control was detected in the Triton series.

Other researchers (3, 8) have reported that autumn applications of surfactant eradicated the powdery mildew fungus better than spring applications. Applications at leaf fall may be a more practical approach than late winter sprays in Ohio due to severe winter weather which often makes orchard spraying extremely difficult. Although secondary mildew infection is affected by surfactants (8), this is probably related to eradication of overwintering mycelium which is most clearly evident as a reduction of primary mildew.

The mildew evaluations reported here were probably taken too late to assess the effect of surfactants solely on primary mildew. However, it must be emphasized that powdery mildew was extremely scarce in 1977 and treatment effects were difficult to determine.

Bloom delay of approximately 9 days occurred when the 5% rate of Triton X100, Triton N57, Triton CS7, and Offshoot T was applied. Although other researchers considered bloom delay caused by surfactants as detrimental, this effect could be viewed as a potential technique for frost protection. Presently, however, much remains unknown, and additional research to evaluate the effect of dormant applications of surfactants on disease control, bud development, fruit set, and yield is underway at OARDC.

LITERATURE CITED

1. Anderson, H. W. 1956. Diseases of Fruit Crops. McGraw-Hill, New York, Toronto, and London.
2. Burchill, R. T. 1958. Observations on the Mode of Perennation of Apple Mildew. Rep. Long Ashton Res. Stn. for 1957, pp. 114-123.
3. Clifford, D. R. and E. C. Hislop. 1975. Surfactants for the Control of Apple Mildew. Pestic. Sci., 6:409-418.
4. Evans, E., J. Marshall, B. J. Couzens, and R. L. Runham. 1970. The Curative Activity of Non-ionic Surface-Active Agents Against Some Powdery Mildew Diseases. Ann. Appl. Biol., 65:474-480.
5. Frick, E. L. and R. T. Burchill. 1972. Eradication of Apple Powdery Mildew from Infected Buds. Plant Dis. Reptr., 56:770-772.
6. Furmidge, C. G. L. 1959. Physico-Chemical Studies on Agricultural Sprays. III. Variation of Phytotoxicity with the Chemical Structure of Surface-Active Agents. J. Sci. Food Agr., 10:419-425.

7. Hislop, E. C. and D. R. Clifford. 1974. Eradication of Powdery Mildew from Apple Buds. Plant Dis. Reptr., 58:949-951.

8. Hislop, E. C. and D. R. Clifford. 1976. Eradication of Apple Powdery Mildew (*Podosphaera leucotricha*) with Dormant Season Sprays of Surface Active Agents. Ann. Appl. Biol., 82: 557-568.

9. Kirby, A. H. M. and E. L. Frick. 1963. Greenhouse Evaluation of Chemicals for Control of Powdery Mildews. III. Experiments with Surface-Active Agents. Ann. Appl. Biol., 52:45-54.

10. Kirby, A. H. M., E. L. Frick, R. T. Burchill, and M. H. Moore. 1963. Effect of Didecyldimethylammonium Bromide Against Powdery Mildews and Other Fungal Plant Diseases. Nature, London, 197:514.

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